Instruction Manual

Model 72B

Capacitance Meter

1281

BOONTON

BOONTON ELECTRONICS CORPORATION ■ 499 POMEROY ROAD ■ P.O. BOX 122 ■ PARSIPPANY, NEW JERSEY 07054 U.S.A.
(201) 887-5110 TWX: 710-986-8241

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CHAPTER I

INTRODUCTION

1.1 GENERAL

The Model 72B Capacitance Meter provides instant, direct reading, three-terminal and differential capacitance measurements from 0.01 to 3000 pF. This coverage is divided into 8 ranges, selected either by the front panel switch or remotely, arranged in a 1 - 3 - 10 sequence. The solid-state design and crystal-controlled signal source contribute to the high stability and excellent reliability of the instrument.

The 1 MHz test signal is held to a level of 15 mV rms (*Note:* Option -03 is 100 mV), allowing the measurement of capacitance of semi-conductor devices. The provision for application of dc bias to either or both sides of the specimen makes it possible to measure these devices under operating conditions. The bias voltages may be applied either to the rear-panel terminals provided or to the appropriate pins on the edge connector.

The Model 72B employs an unusual range-switching system using switching diodes and miniature reed relays; the elimination of the switch contacts from the measurement circuits assures a maximum of reliability and stability. The phase-sensitive detector system permits the measurement of even low-Q devices (down to Q = 1) without sensibly degrading the accuracy of the measurement.

Two plug-in connection adapters are supplied with the Model 72B. One adapter, fitted with two sets of coaxial connectors, 72-4B, is intended for use with coaxial cables and remotely located test fixtures for both three-terminal and differential measurements. The second adapter, 72-5C, with three terminal posts, is for wire-lead type components; differential measurements are not possible with this adapter.

A linear dc output is available at rear panel terminals as well as at the appropriate pins on the edge connector. This feature extends the range of applications beyond ordinary laboratory measurements to include production testing as well as a variety of control functions. Flexibility is further enhanced by the provision of remote ranging terminals; the instrument is fully capable of integration into a controlled test system for rapid, production-line testing.

Remote ranging is controlled by grounding the MANUAL DISABLE terminal on the rear edge connector, disabling the front panel range switch. Grounding any one of the eight range-line terminals will then select that range.

Connection to the rear panel edge connector should be made with an Amphenol Type 225-22221-101 plug.

CHAPTER II

SPECIFICATIONS

Capacitance Range:	0.01 to 3000 pF
Full Scale Ranges:	1, 3, 10, 30, 100, 300, 1000, 3000 pF
Accuracy:	
1 - 1000 pF fs	±0.5% rdg ±0.5% fs (Q > 5)*
	±1.0% rdg ±0.5% fs (Q = 1 to 5)*
3000 pF fs	±1.0% rdg ±0.5% fs (Q > 5)
	±2.0% rdg ±0.5% fs (Q = 1 to 5)
	*add 0.005 pF on 1 pF fs range
Resolution:	0.5% of fs on all ranges
Meter:	4-1/2" taut-band type; two linear scales, 0 to 10 (0.1 per division), and 0 to 30 (0.5 per division)
DC Output:	1 volt fs, adjustable ±2% at 1, 10, 100, 1000 pF
	3 volts fs, adjustable ±2% at 3, 30, 300, 3000 pF
Linearity:	±0.1% rdg ±0.01% fs
	3000 pF range: ±0.25% rdg ±0.01% fs
Response Time:	1 msec
Source Resistance:	1 kΩ
External Bias:	HI to GND: ±200 V max.
	LO to GND: ±400 V max.
	LO to HI: ±600 V max. (floating supply only)
Test Signal:	1 MHz, crystal-controlled; 15 mV rms; Option -03, 100 mV rms

Temperature Influence:

Temperature Range	Max. Influence
Reference 21°C to 25°C	0
Normal 18°C to 30°C	0.2% of rdg
Extreme 10°C to 40°C	0.5% of rdg

Accessories Furnished: Two connection adapters:

a) 72-4B BNC for remote connections to TEST and DIFF terminals

b) 72-5C grip-posts for local connection of axial-lead components

Accessories Available: Single rack-mounting kit (mounts left or right) 92-1A
Dual rack-mounting kit 92-1B

Power Requirements: 100, 120, 220, 240 V ac - selectable on rear panel; 50 to 400 Hz; 7 watts

Dimensions: 5.2" high, 8.3" wide, 12" deep (132 x 211 x 305 mm)

Weight: Net 7 lbs. (3.15 kg)

CHAPTER III

OPERATION

3.1 INSTALLATION

Each instrument has been inspected and tested at the factory for full compliance with all specifications before packing. Should any indication of shipping damage be apparent upon unpacking, be sure to notify the carrier and the factory immediately. It is recommended that the special packing materials be saved for use in the event that the instrument must be reshipped in the future.

3.1.1 Operating Controls and Indicators

ITEM	FUNCTION
FULL SCALE pF	This switch selects the full-scale range of the instrument; it has 8 positions ranging from 1 pF to 3000 pF, full-scale.
PWR Switch	This rocker-type switch turns on the ac primary power. The translucent plastic rocker also serves as the pilot light.
ZERO Control	This control operates a differential capacitor to balance out capacitance across the TEST terminals contributed by exposed terminations of connecting cables, test fixtures, etc. This is a dual ratio control, with low torque over 270° of rotation, shifting to a higher torque vernier ratio beyond this point. The control has a range of approximately plus and minus 5 pF.
METER	A 4-1/2 inch taut-band meter with two linear scales, reading 0 to 10 with 0.1 per division, and 0 to 30 with 0.5 per division.
	(The following items are on the rear panel.)
ANALOG OUTPUT Terminals	A dc voltage proportional to the meter reading is available at these terminals, adjustable ±2%. fs output: 1 volt (1-series ranges), 3 volts (3-series ranges) Source resistance: 1 kΩ

BIAS Terminals

External dc bias may be applied to the HI and LO Test terminals via these posts. The maximum values are ±200 volts from HI terminal to ground, and ±400 volts from the LO terminal to ground. It is recommended that the terminal not biased be connected to ground. The sum of these two voltages (600 V dc) may be applied between the HI and the LO posts, but the bias supply should be floating (no connection to ground) for this application.

LINE VOLTAGE Switch

This switch must be set to the appropriate line voltage - 100, 120, 220, or 240 volts, 50/400 Hz.

Fuse Holder

This contains the main line fuse, which should be either a 0.06 ampere for 220/240 V or a 0.10 ampere for 100/120 V.

P102

A 22-pin edge connector for remote ranging and output connections. (See Figure 9 for pin designations.)

Test Adapter

These banana plugs are used for storing the unused connection adapter, either a 72-4B or a 72-5C.

This safety requirement symbol has been adopted by the International Electrotechnical Commission, Document 66 (Central Office) 3, Paragraph 5.3, which directs that an instrument be so labeled, if, for the correct use of the instrument, it is necessary to refer to the Instruction Manual. In this case it is recommended that reference be made to the Instruction Manual when connecting the instrument to the proper power source.

3.2 OPERATION

3.2.1 See that the rear-panel voltage selector switch is in the proper position for the line voltage used. Adjust (if necessary) the mechanical zero screw of the meter, plug the instrument into a power outlet, and allow it to warm up for a few minutes.

3.2.2 Plug the appropriate test connection adapter into the front panel receptacle. If remote or other coaxially-connected components are to be measured, connect all cables and test fixtures to the TEST jacks of the connection adapter. The test adapter is held in place by a captive screw located in the center of the adapter.

3.2.3 Switch the instrument to the lowest range (1 pF fs). Set the meter reading to zero, using the ZERO control.

NOTE: The ZERO control uses a dual-ratio vernier to drive a variable air capacitor having a full 360° of rotation. The ZERO control turns easily for about 270°, at which point the ratio shifts from 36:1 to 6:1 and torque increases abruptly.

3.2.4 When more than a few inches of coaxial cable is used to connect the instrument to a remote test fixture, some attention must be given to the shunt capacitance of the cable. To maintain the specified accuracy, the values shown in the following table should not be exceeded.

MAXIMUM CABLE SHUNT CAPACITANCE

A. HI post to ground:

RANGE	MAX. C
1 pF & 3 pF	200 pF
10 to 3000 pF	500 pF

B. LO post to ground:

500 pF max. on all ranges

3.2.5 The instrument is now ready for use. Once the zero setting has been made on the lowest range, it will hold on all other ranges.

3.2.6 The ZERO adjustment has sufficient range to compensate for approximately 5 pF of shunt capacitance across the TEST terminals. If this range is insufficient, a small capacitor (value determined experimentally) can be connected across the DIFF terminals to effect zero setting within the range of the ZERO control.

3.2.7 Remote Measurement

The remote measurement of capacitance via coaxial cables introduces a measurement error owing to the transmission line effect on the test voltage transmitted from the LO terminal, and on the received current at the HI terminal.

The combined effect is such that the ratio of measured capacitance to actual capacitance is

$$C_m/C = \frac{1 + j\omega Cr}{[\cos \beta\ell - \omega C Z_o (\sin \beta\ell)]^2 \left[1 + j\, \dfrac{\omega Cr\ (\cos \beta\ell) + (\sin \beta\ell) r/Z_o}{\cos \beta\ell - \omega C Z_o\ (\sin \beta\ell)}\right]}$$

where $\beta\ell$ = the electrical length of each line, in degrees

Z_o = the characteristic impedance of the line, in ohms (*NOTE:* at 1 MHz, Z_o for RG-58/U is approximately 56.5 ohms and relative velocity is 63.5%.)

and r = the equivalent resistance of the Capacitance Meter from HI terminal to ground.

Range	r
1 pF and 3 pF	140 ohms
10 pF and 30 pF	7 ohms
100 pF and above	1 ohm

For the 72B Capacitance Meter, the error is positive and its magnitude is shown in Figure 1 as a function of the measured capacitance, C_m, and cable length, ℓ.

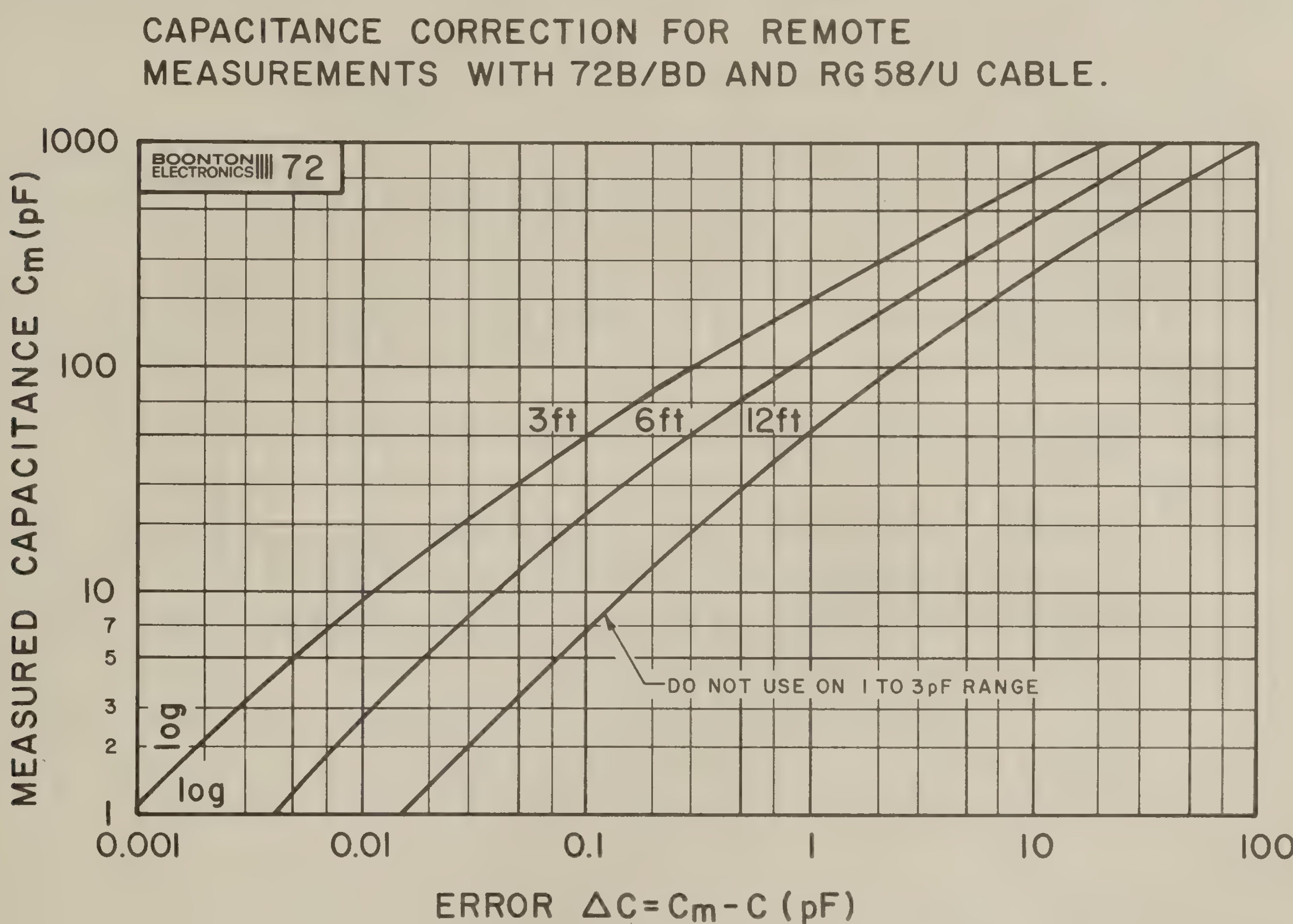


Figure 1.

The error is not shown for the lower two ranges for 12 foot lengths of cable, as the capacitive loading of the HI test terminal is excessive for lengths of RG-58/U greater than about 3.5 feet, and lengths of about 8 feet for the 10 pF and 30 pF ranges.

When calculating $\beta\ell$, which is the electrical length of degrees of each of the two cables, it is necessary to know the velocity of propagation of the cable at 1 MHz. Samples of RG-58/U which were tested indicate a relative velocity of 63.5%. The impedance of the same cable measured 57.5 ohms at 1 MHz.

It is imperative that the shields of both ends of the coaxial cable be tied together with a low resistance, low inductance strap for the correction curves and equation to be valid.

3.2.7.1 For short lengths of cable, a reasonable correction may be made based upon the effect of the series inductance of both lengths of cable. The measured capacitance, C_m, of a specimen will differ from the true capacitance, C_t; the error will be seen as an apparent increase in capacitance in accordance with the following expression:

$$C_m = \frac{C_t}{1 - \omega^2 L C_t} = \frac{C_t}{1 - (X_L/X_{C_t})}$$

Or, if the true capacitance is required:

$$C_t = \frac{C_m}{1 + \omega^2 L C_m} = \frac{C_m}{1 + (X_L/X_{C_m})}$$

Where L = the combined series inductance of BOTH lengths of connecting cables and the inductance of the sample (generally small with respect to the cable's inductance).

As an approximation, the inductance/foot of RG-58/U cable (with shields common at both ends) is about 0.091 μH.

3.2.8 Differential Measurements

Measurement of the differential capacitance between two specimen capacitors can be made by connecting the smaller sample to the DIFF terminals, and the larger to the TEST terminals. The display will indicate the difference in capacitance between the two; by switching down to the next lower range the resolution will be improved. The capacitance connected to the DIFF terminals may be as large as the full-scale value of the selected range without introducing serious error. The larger capacitance must be on the TEST terminals, which will give a positive and negative indication for differential measurements.

Excess fixture capacitance across the TEST terminals beyond the normal range of the ZERO control may be balanced out by the addition of a capacitor to the DIFF terminals (see Paragraph 3.2.6).

3.2.9 DC Bias

DC bias voltage may be applied to either or both sides of the specimen via the rear-panel bias terminals, or the proper pins on the rear edge connector. The applied voltages should not exceed ±200 volts from the HI terminal to ground, or ±400 volts from the LO terminal

to ground. When bias is applied to one side only, it is recommended that the other bias terminal be connected to ground.

The sum of the two voltages (600 volts dc) may be applied between the HI and the LO terminals. In this connection the bias supplied should not be grounded. (An internal voltage divider of resistance values of 240 kΩ from HI to ground and 510 kΩ from LO to ground establishes the ground point.) The bias lines are internally protected by 30 mA fuses.

3.2.10 Extended DC Bias

If external bias voltages larger than allowed in Paragraph 3.2.9 are required, the circ of Figure 2 should be used.

$C_2 \approx 200 (C_{TEST})$, WITH VOLTAGE RATING > E
L_1 AND C_1 TO RESONATE AT 1MHz. $Q\omega L_1 > 200K$ ($L_1 \approx 150\mu H$; $Q > 200$)
$RC \leq 0.002$ SECONDS.
$C_2 \times L_2 = 25330$ (pF AND μH)
KEEP C_2 HIGH AND L_2 SMALL. i.e., 0.01 μF AND 2.5 μH.

NOTE: L1 MAY BE ORDERED FROM BOONTON ELECTRONICS CORPORATION, PART NO. 400124.

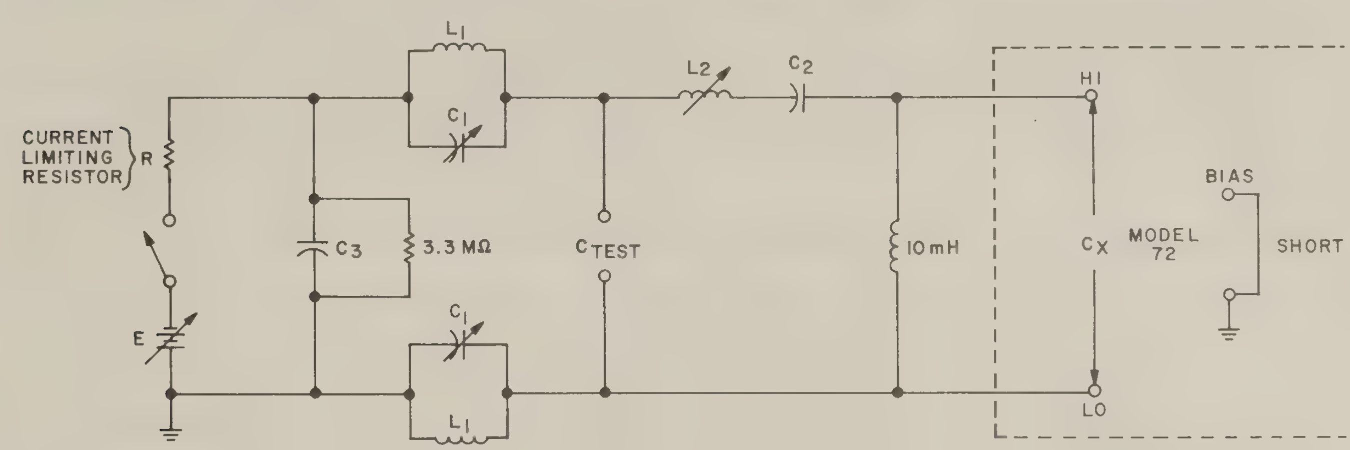


Figure 2. Connections for External Bias

CHAPTER IV

APPLICATIONS

4.1 TRANSISTOR PARAMETERS

The Model 72B is capable of measuring the small-signal capacitance and forward gain parameters of both bipolar and unipolar transistors at 1 MHz. Capacitance and transconductance are measured with a test signal level of 15 millivolts; beta is measured with a base signal current of approximately 100 nanoamperes. Model 72B-03 (100 mV test signal level option) is not recommended for these measurements.

The principle of operation of the 72B is fundamentally that of a transmission test set; the test capacitance is interposed between a low-level signal generator of fixed known amplitude and phase, and a calibrated phase-sensitive detector. It is evident that the forward gain parameters of transistors may also be measured, provided that the phase of the output current is proper, or suitably altered. The necessary external circuitry and components are described in the following text. Parameters that can be measured include the following:

4.1.1 Capacitance (Three-Terminal) (See Figure 2.)

NOTE: When measuring the capacitance of transistors, it is imperative to remember that a signal applied to the input of the test device will appear amplified in some form at the output (usually with a phase reversal). Capacitance measurements must be made with the output of the device connected to the low test-terminal (generator) and the input of the device connected to the high test-terminal (detector).

C_{rss} Reverse transfer capacitance between drain and gate. Source guarded. Device under test is fully biased. $V_{GS} = 0$.

C_{eb} Emitter-to-base capacitance. Collector guarded. Emitter reverse biased. $V_{CE} = 0$ (o.c. for dc).

C_{ce} Collector-to-emitter capacitance. Base guarded. Collector reverse biased. $V_{BE} = 0$ (o.c. for dc).

C_{re} Collector-to-base capacitance. Emitter guarded. Device under test is fully biased.

C_{cb} Collector-to-base capacitance. Emitter guarded. Collector reverse biased. $I_E = 0$ (o.c. for dc).

4.1.2 Capacitance (Two-Terminal)

C_{oss} Output capacitance between drain and source with gate ac connected to the source. Device under test is fully biased. $V_{GS} = 0$.

C_{iss} Input capacitance between gate and source with drain ac connected to the source. Device under test is fully biased. $V_{GS} = 0$.

C_{ob} Collector-to-base capacitance. Emitter is open-circuited for both ac and dc. Collector is reverse biased.

4.1.3 Beta (h_{fe})

A sensibly constant base current, i_b, of 94 nanoamperes can be generated with the aid of a 1.0 pF capacitor connected between the low differential (LO DIFF) terminal of the 72B Capacitance Meter and the base of the transistor under test. The collector current, which equals βi_b, is fed to the high test terminal (HI TEST) and the instrument responds as though a capacitance of β times 1 pF were connected to its terminals. The value of indicated capacitance in picofarads is equal to beta (h_{fe}). The measurement of beta should be made under full bias conditions. In this arrangement, the base current is independent (very nearly) of the input resistance of the transistor, owing to the quadrature relation between the reactance of the current source and the input resistance.

The low differential terminal is used for the current source to offset the 180-degree phase reversal of current in the transistor.

The variable series capacitor in the base circuit (see Figure 3) must be adjusted for a value of 1.0 pF. This is simply accomplished by connecting a small jumper (unity-gain transistor) between the base and collector socket terminals, which permits the direct measurement of this capacitance. If the LO DIFF terminal is used, the reading should be adjusted for -1.0 pF, using the dc recorder output, or the LO TEST terminal may be temporarily used for a reading of +1.0 pF on the meter.

Should the transistor socket and its associated circuitry have excessive capacitance from the base terminal to ground, it can be absorbed with a simple parallel-resonant circuit, using a high L/C ratio for maximum impedance (Figure 3).

4.1.4 Forward Transconductance (g_{fs})

The 72 Series Capacitance Meters are calibrated for an input current of $+je_g\omega C$, where C is the full-scale value of capacitance for any given range. Connecting the gate of a unipolar transistor

to the LO TEST terminal will, by definition, generate a drain current of $e_g g_{fs}$, provided that the external drain-circuit impedance is small. Unfortunately, the phase of the drain current lacks the required +90 degrees.

A network is needed which presents a low impedance to the drain, and which provides the necessary phase shift of +90 degrees. The circuit shown in Figure 4 satisfies these conditions. The resistor R is the calibrating resistor for the full-scale value of g_{fs}. Its value is readily derived. The instrument is calibrated for a high terminal-current of,

$$i_c = e_g \omega C \underline{/90°}$$

The actual drain current is,

$$i_d = e_g g_{fs}$$

The voltage induced in the secondary of the transformer is,

$$e' = j i_d \omega M \underline{/90°} \quad \text{(polarity arranged for +M)}$$

To achieve a full-scale indication for a given value of g_{fs} the resistor R must have the value

$$r = e'/i_c = \frac{e_g g_{fs} \omega M \underline{/90°}}{e_g \omega C \underline{/90°}} = g_{fs} M/C$$

where

$R \gg \omega L_s$ for the current to have the correct phase; M is the mutual inductance of the transformer and equals,

$$M = k \sqrt{L_p L_s}$$

The coefficient of coupling, k may be easily measured by measuring the primary inductance with the secondary open-circuited, then short-circuited.

$$k = \sqrt{1 - (L_{sc}/L_{oc})}$$

If the resistor R is selected for a full-scale reading of 1000 µmhos on the 100 pF range, the instrument will read:

C Range	g_{fs} Range
100 pF	1000 µmhos
300 pF	3000 µmhos
1000 pF	10,000 µmhos
3000 pF	30,000 µmhos

A typical toroidal transformer might have the following circuit values:

L_p = 250 µH

L_s = 5 µH

k = 0.935

from which,

$$M = 33\ \mu H$$

The series primary capacitance for resonance must equal 100 pF (approximately) and for a full-scale range of 1000 μmhos on the 100 pF range, the calibrating resistor should equal:

$$R = (1000)\ (33)/100 = 330\ \Omega$$

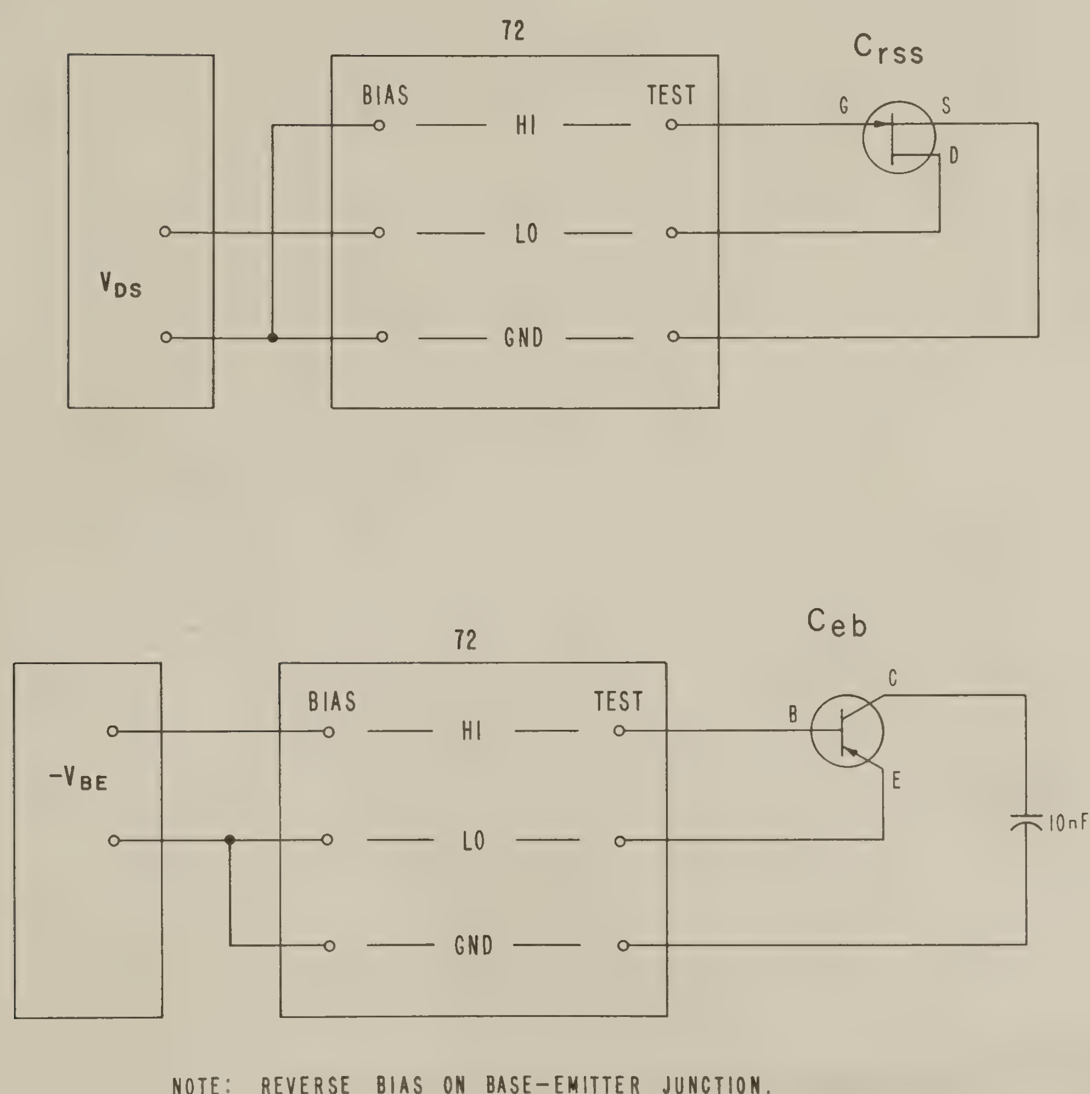
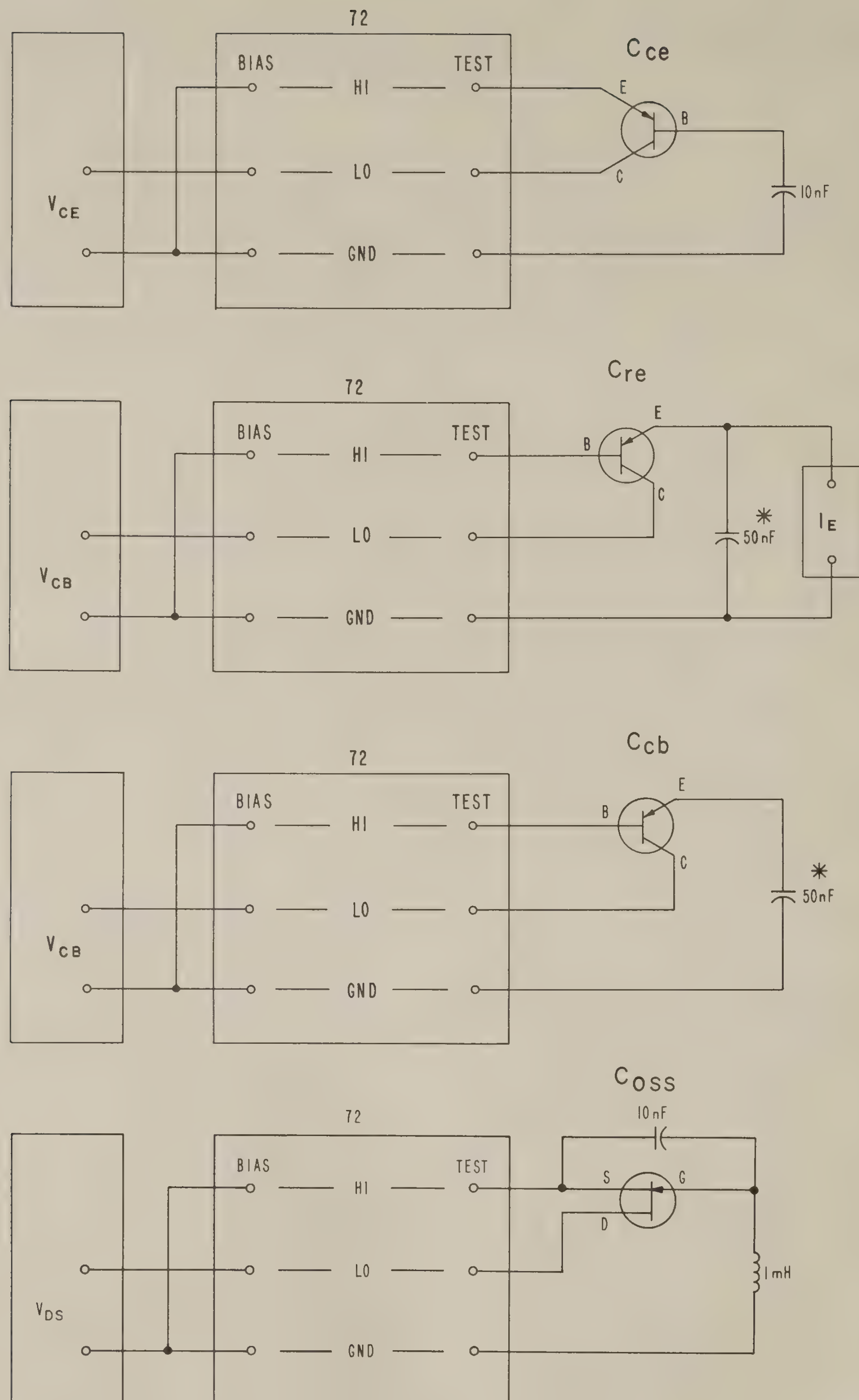
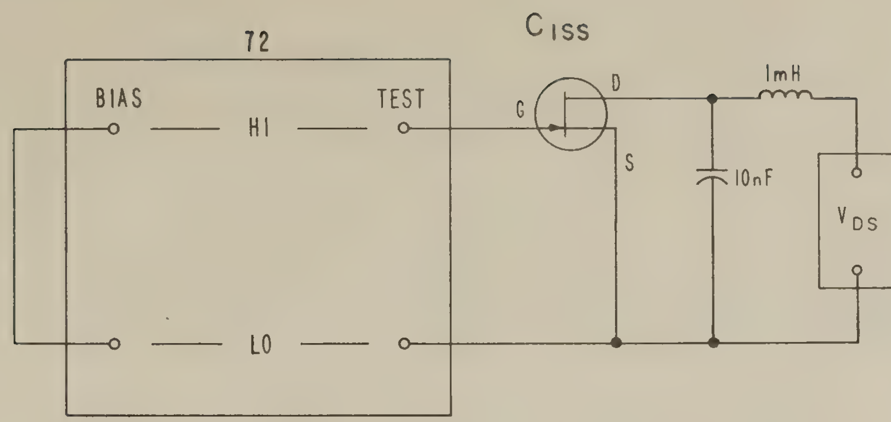


Figure 2. Transistor Capacitance Measurements



*A better by-pass obtains with a 2.5 μH inductor in series with a 0.01 μF capacitor.

Figure 2. Transistor Capacitance Measurements (Continued)



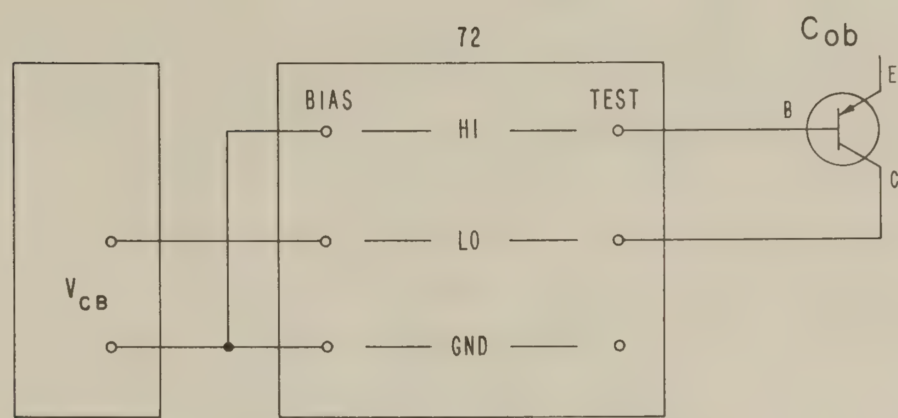


Figure 2. Transistor Capacitance Measurements (Continued)

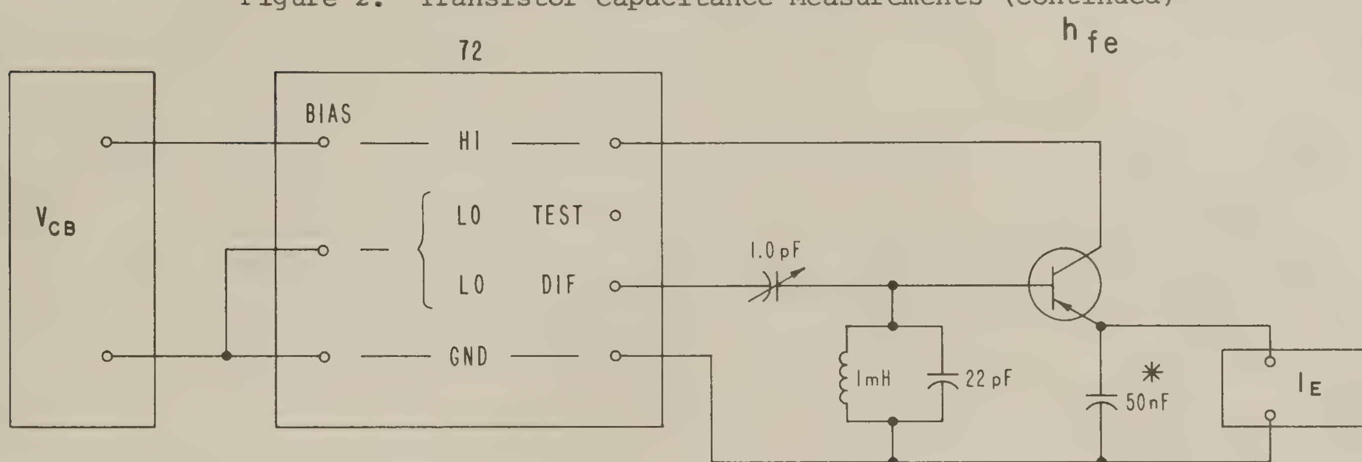
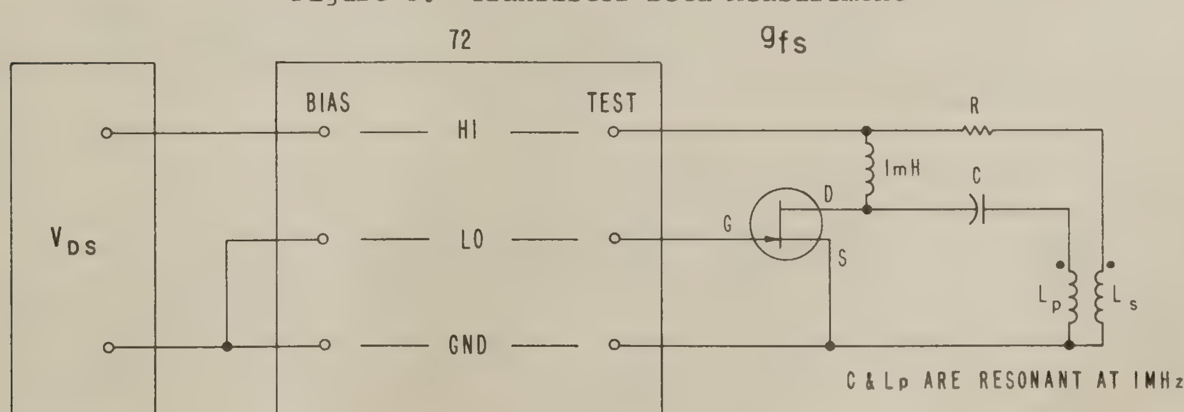


Figure 3. Transistor Beta Measurement



*A better by-pass obtains with a 2.5 H inductor in series with a 0.01 μF capacitor.

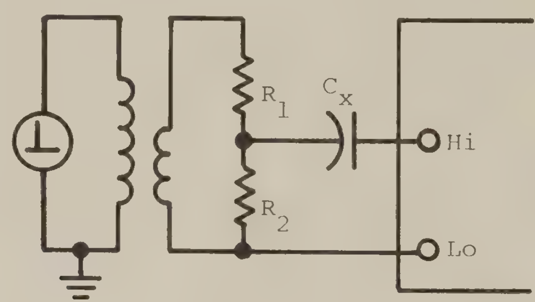
Figure 4. Transistor Transconductance Measurement

4.2 PULSE BIAS AND OUTPUT RISE-TIME

4.2.1 Pulse Bias

The internal bias circuit of the 72B needs adequate bypassing for the 1 MHz test signal and is therefore unsuitable for the application of pulses to bias the test specimen.

Pulse bias can be applied, however, through the external circuitry. A simple arrangement is shown in the following figure. If the impedance of the pulse transformer secondary is small, relative to R_1, the test specimen may be considered to be in series with a resistance of $R_1R_2/(R_1 + R_2)$ ohms. This value need only be less than about 1/5 of the reactance of the test capacitor, at 1 MHz, in order to be ignored by the phase detector in the capacitance meter.



The ratio of the two resistors, and their absolute values, will depend upon the pulse transformer and its load matching requirements, as well as the nature and magnitude of the pulse needed for bias.

4.2.2 Rise-Time

The rise-time of the analog output can be reduced by removing the bypass circuitry in this section of the instrument. The cost of this improvement is an increase in the residual noise at the output terminals.

The normal rise-time is < 1 ms and the rms noise is < 1 mV. If C131 is removed, the rise-time will be reduced to < 175 μs and the noise will be < 3 mV.

CHAPTER V

THEORY OF OPERATION

(Refer to the Simplified Schematic, Figure 5, in connection with this explanation.)

5.1 BRIDGE CIRCUITS

The output of the 1 MHz crystal-controlled oscillator appears across the secondary of the transformer whose center-tap is at RF ground. One end of this winding goes to the LO TEST terminal, and the other end to the LO DIFF terminal. The HI terminals are connected together and lead to the measuring section. A differential capacitor (ZERO) has its stators connected across the transformer secondary winding, and its rotor to the common HI post connection.

With the instrument operating, and with both TEST and DIFF terminals open, the only signal appearing at the output of this section would be the result of the residual capacitances of the terminals and any fixtures connected to them. Adjustment of the differential capacitor (ZERO control) balances out this signal, within the limits specified in Section 3.2.4, resulting in zero output from the measuring section.

When a specimen capacitor is connected between the LO and HI TEST terminals, a current directly proportional to its susceptance flows through the low-impedance series-resonant LC circuit to ground. (The series resonant circuits for each range are selected by the range switching circuits.) The resultant voltage appearing across the capacitive part of the series circuit is applied, through a tuned amplifier, to the synchronous detector.

The synchronous detector, gated by the crystal oscillator, converts the 1 MHz signal to dc and applies it to the dc amplifier section. The output of the dc amplifier drives the panel meter and a voltage divider which supplies an adjustable analog output at the rear terminals and also on the rear connector P102 for external indication or control purposes.

5.2 RANGING CIRCUITS

Range switching in the 72B is accomplished by a combination of the panel range switch, switching diodes, and miniature reed relays. The panel switch handles only control voltages; no signal currents pass through its contacts, which eliminates a frequent source of errors and improves reliability.

The switching diodes are biased off by the 2.4 volt differential between the +6.6 volts on the cathode and the +4.2 volts on the anode. When range switch contacts are closed, the cathode

of the appropriate diode is grounded for dc through an rf choke and 10 kΩ resistor. As it then has a net positive bias on its anode, the diode is switched to the conducting state and thereby connects one end of its associated range network to the input of the 1 MHz amplifier. At the same time, the range switch energizes the associated reed relay through a logic circuit which then connects the other end of the range network to the output of the measuring section.

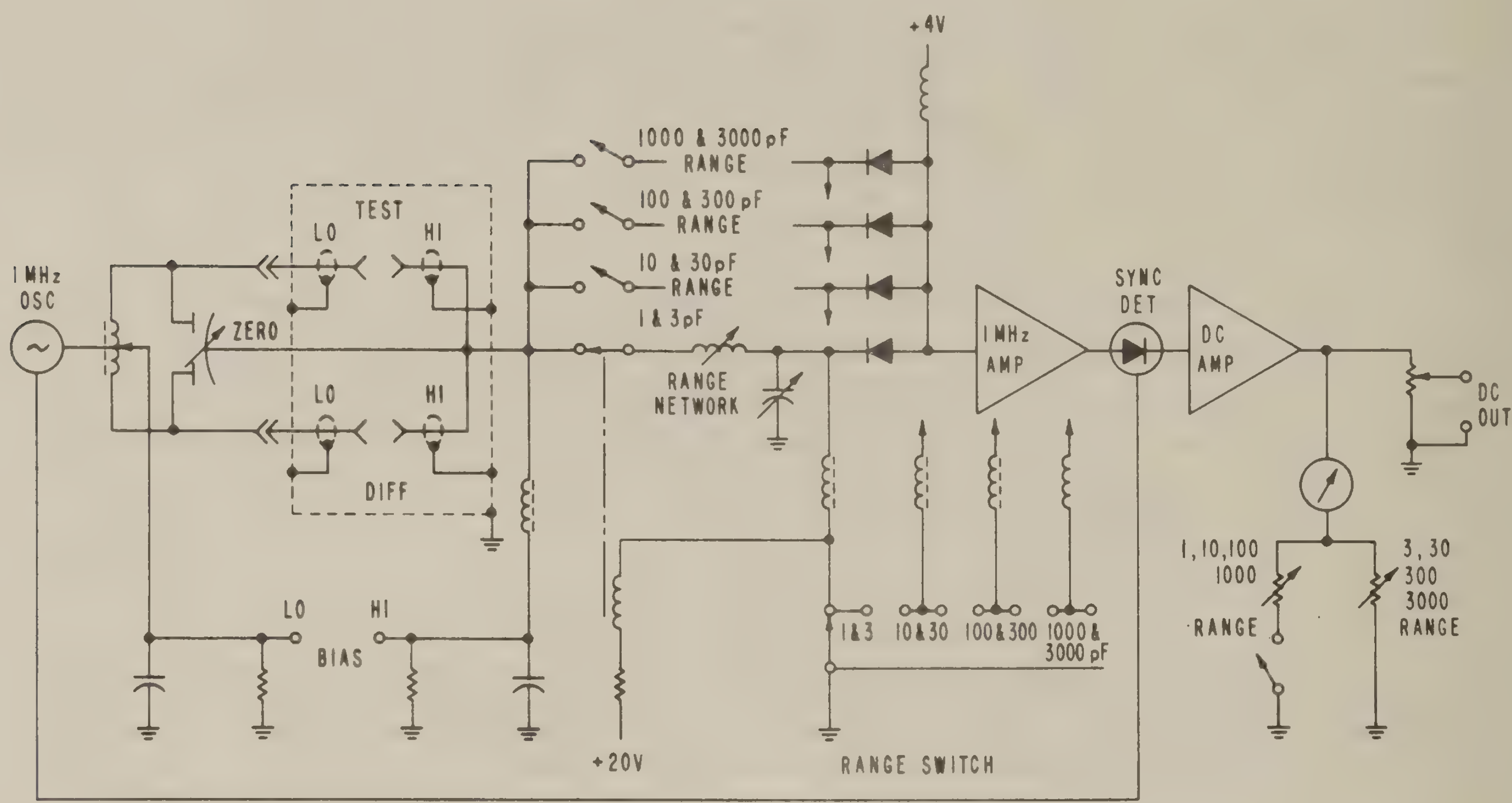


Figure 5. Simplified Schematic

CHAPTER VI

MAINTENANCE

NOTE: Values and tolerances shown in this section are not specifications but are provided only as guides to the maintenance and calibration of this instrument.

6.1 Introduction

The Model 72B is designed to operate within stated specifications over a long period. However, to achieve the maximum performance it is desirable to check and adjust the instrument periodically. Basically, two adjustments are recommended:

a. A zero balance check and adjustment every 500 hours of operation (three months of normal use), and

b. A calibration check every 1000 hours of operation (six months of normal use).

In addition to these two periodic checks, complete adjustment procedures are described in Paragraphs 6.4 to 6.9. It is felt, however, that after the complete calibration procedures performed at the factory, *these adjustments are not needed when the instrument is used in normal laboratory or factory environment.* It is recommended they be performed only in case of accidental misadjustment, component failure and replacement, or when the instrument has been subjected to severe environmental stresses, such as shock or vibration.

Complete schematics, parts lists, and control and component location drawings are at the end of this manual and should be referred to when servicing is performed.

For all calibration checks a minimum one hour warmup is required.

6.2 Required Test Equipment

6.2.1 Digital or differential dc voltmeter, 0.001 - 100 V; ±0.05% accuracy (Fluke Model 8100 or equivalent.

6.2.2 DC VOM, 1 MΩ input resistance.

6.2.3 RF Millivoltmeter, 1 mV to 1 V, 1 MHz minimum bandwidth (Boonton Model 93A with high impedance probe).

6.2.4 Capacitance and Q Standards, 100 pF ±0.25%, Q > 500 and Q ≈ 3 at 1 MHz (Boonton Model 71-1A) and a set of 1 MHz capacitance standards:

1000 pF ±0.1% (Boonton Model 76-1A)

300 pF ±0.1% (Boonton Model 76-1A)

100 pF ±0.1% (Boonton Model 76-1A)

10 pF ±0.1% (Boonton Model 76-1A)

1 pF ±0.1% (Boonton Model 76-1A)

6.2.5 1 to 1000 pF ±0.1% Push Button Capacitance Standard (Boonton Model 76-3A).

6.2.6 200 pF ±5% loading capacitor (See Section 6.5.2.1).

6.2.7 500 pF ±5% loading capacitor (See Section 6.5.2.1).

6.3 Zero Adjustment

The zero adjustment should be performed whenever there is disagreement between higher range zeros after the zero has been adjusted on the lowest range with the front panel ZERO control. No standards or equipment are needed to perform this check and adjustment.

6.3.1 To check the zeros with no capacitance on the TEST terminal, set the Model 72B to the lowest range and adjust the front panel ZERO control for zero indication. Now select all higher ranges and observe and record zero indications on all higher ranges. The indications should not exceed ±0.5% fs. If the zero indication exceeds these limits, proceed as follows:

6.3.2 Adjustment

6.3.2.1 Turn the instrument OFF and check the indicator pointer in normal instrument operation position. Adjust the meter zero (black screw below the dial) to indicate exactly zero.

6.3.2.2 Turn the instrument on, connect the BNC adapter to the instrument, but use no capacitor, and adjust the front ZERO control on the 1 pF range until the instrument indicates zero.

6.3.2.3 Select the 1000 pF range and adjust R133 at the rear until the instrument indicates zero on the 1000 pF range.

6.3.2.4 Set the instrument to the 1 pF range and adjust the front ZERO again. Now check all other ranges, which should be in the ±0.5% fs limits.

If desired, the 1000 pF range zero (R133) may be reset slightly to make the maximum positive zero deviation equal to the maximum negative deviation. This will minimize the zero error

when the instrument is used on different ranges without front ZERO adjustment.

6.4 Calibration Check

The calibration check should be performed periodically after approximately every 1000 hours of operation. For the calibration check a set of capacitance standards of 1, 10, 100, 300, and 1000 pF is needed.

6.4.1 To check the calibration allow a minimum of one hour warmup and *adjust the zero with the front ZERO control at every range* before making measurements. Perform Zero Adjustment 6.3 if needed.

Connect 1, 10, 100, 300, and 1000 pF standards and check the errors on the corresponding ranges. These errors should not exceed 0.5% on any range. Record the indications.

Before making further adjustments, analyze the results. If all ranges have errors in the same direction and approximately by the same percentage, a simple test level adjustment will correct the calibration. However, when ranges need adjustment in different directions (some have positive, some negative errors) or by different amounts, they have to be calibrated separately.

6.4.2 Calibration Adjustment

When all ranges have drifted by approximately the same amount, a single test level adjustment will correct the calibration.

6.4.2.1 Test Level Adjustment

For the test level adjustment, warm up the instrument, remove the top cover, select the 100 pF range, zero the range, and connect a 100 pF ±0.1% standard to the TEST terminals. If the indication is not within 0.5% of the standard, adjust the ten-turn trimmer R202 on the amplifier plug-in board to give the correct reading within 0.1%. By this adjustment, indications on all ranges will be corrected by the same percentage. The test level is also changed by this adjustment but this change is usually insignificant. The zeros of the ranges will not be affected.

The same result may be achieved by adjusting R142 on the 100 pF range which corrects all "1" ranges and R146 on the 300 pF range which corrects all "3" ranges by the same percentage.

6.4.2.2 For individual range adjustments, the instrument's bottom cover has to be removed to allow access to calibration adjustments C111, C117, and C121 on the lower left side of the

instrument. To shield the instrument during these adjustments, the instrument should be set on a plain aluminum sheet, or use a test cover with appropriate access holes.

The adjustments should always start with R202 (6.4.2.1) on the 100 pF range because this adjustment affects all other ranges.

For the 1000 pF range, connect the 1000 pF ±0.1% standard to the TEST terminal and, using a 1/16" insulated screwdriver, adjust C121 for an indication within 0.1%.

For the 10 pF range, use a 10 pF standard and adjust C117.

For the 1 pF range, use a 1 pF standard and adjust C111.

For all "3" ranges, select the 300 pF range, use a 300 pF standard and adjust R146 at the rear of the instrument.

Sections 6.3 and 6.4 cover the recommended periodic calibration procedure of the Model 72B. The adjustments in the following section are not recommended to be performed periodically.

6.5 Maintenance and Repair Adjustments

The following adjustments are factory adjustments which are not affected by aging or drift of the components and therefore are expected to remain set during the life of the instrument. Furthermore, their effect on instrument accuracy is somewhat less than the effect of direct calibration adjustments.

Therefore, *it is not recommended that the adjustments described below be made during periodic calibration routine*. They have to be adjusted only when certain characteristics they affect are known to be out of specification, in case of component replacement, accidental misadjustment, or in case the instrument is exposed to abnormal vibration, shock, or frequent transportation.

The characteristic every adjustment affects and the method of adjustment are described below.

6.5.1 Power Supply Adjustments R115 and R118

R115 should be adjusted to make the positive supply +15.0 V ±0.25 V. Use R118 to adjust the negative supply to -15.0 V ±0.25 V.

6.5.2 L102, L103, and L104 Loading Adjustment

The Model 72B is designed for three-terminal measurement, i.e., it measures only the capacitive component between HI and LO terminals and ignores the "loading capacitance" from the HI

terminal or the LO terminal to ground. If jigs or cables with high loading capacitance are used to connect the test capacitance to the Model 72B and an error more than specified due to the capacitive loading is introduced, the loading adjustments L102, L103, and L104 have to be adjusted. It should be kept in mind that long connecting cables themselves introduce measuring error (see Section 3.2.7), especially with high value test capacitance. This error should not be confused with loading error.

6.5.2.1 Loading Error Test

To test for loading error, special loading capacitors of 200 pF and 500 pF should be constructed according to the sketch below:

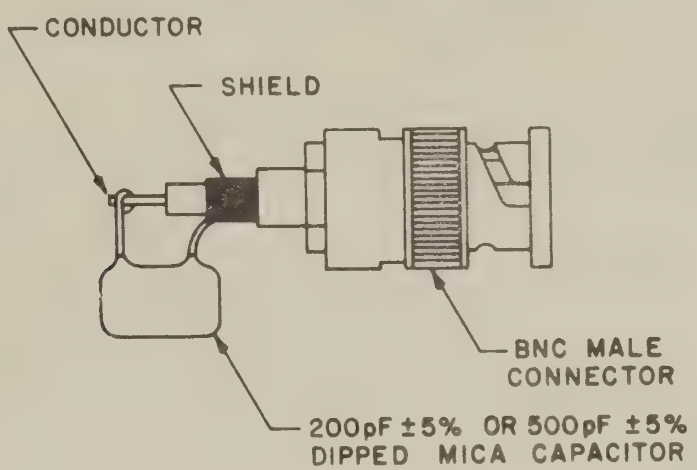


Figure 6. Loading Capacitor

To connect the loading capacitor and the test capacitor, use a BNC adapter with two BNC "TEEs" as shown in the sketch below:

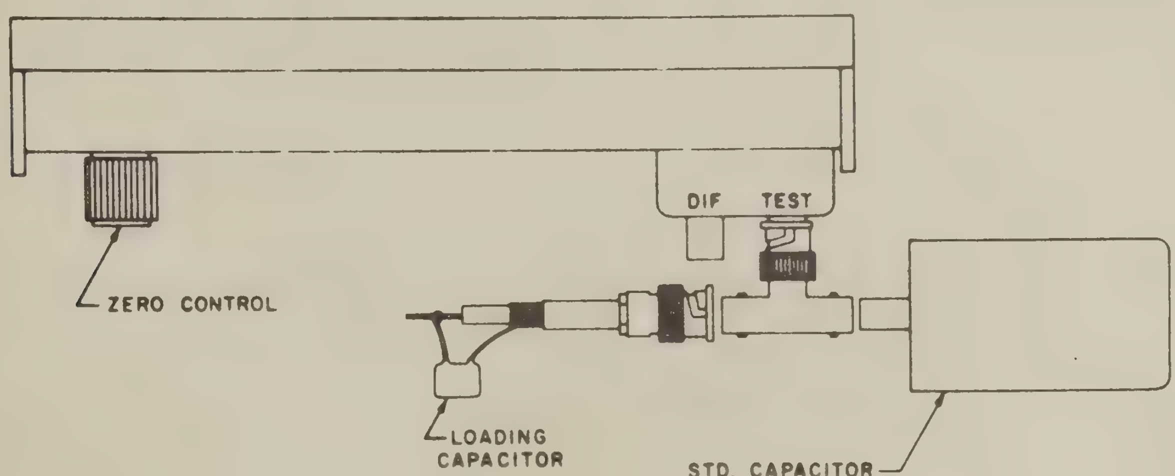


Figure 7. Loading Capacitor Test

For the loading test, select the desired range, connect the BNC adapter with two BNC TEE connectors as shown above, and zero the instrument with the front ZERO control.

Connect the standard capacitor to the right side of the TEE and record the instrument indication. Now disconnect the standard capacitor and connect the loading capacitor to the left side of the TEE on the HI terminal. Zero the instrument again, connect the standard capacitor to the right side of the TEE and measure the standard capacitor again.

The difference between indications should be within the following limits:

HI TERM LOADING	RANGE	MAX DIFFERENCE
200 pF	1, 2, or 3 pF	0.5%
500 pF	10 pF and higher	0.25%

When the HI terminal loading causes more error than listed above, adjust the loading coils as follows:

6.5.2.2 L102, L103, L104 Loading Coil Adjustments

Select the proper range, proper standard and loading capacitor. Only "1" ranges have to be checked because the next higher "3" range uses the same input circuitry.

Zero the instrument and measure the standard capacitor; record the result. Now remove the standard capacitor, connect the loading capacitor to the HI terminal, zero the instrument again, and connect and measure the standard capacitor again. If the measured value does not agree with the previous measurement, adjust:

LOADING ADJUSTMENT	RANGE
L102	1, (2), 3 pF
L103	10, (20), 30 pF
L104	100, (200), 300 pF

The 1000 pF (2000 pF) range is adjusted with the 100 pF range adjustment.

The loading coil adjustment may affect calibration for the same range. Therefore the calibration has to be checked and adjusted per Section 6.4, if desired.

LO terminal loading will not change during the life of the instrument and does not have to be checked.

6.6 HI - LO Q Adjustment C223, C228, and T201

Model 72B measures only the capacitive component and ignores the resistive component of the current between HI and LO terminals. In order to accomplish this, the reference voltage to the

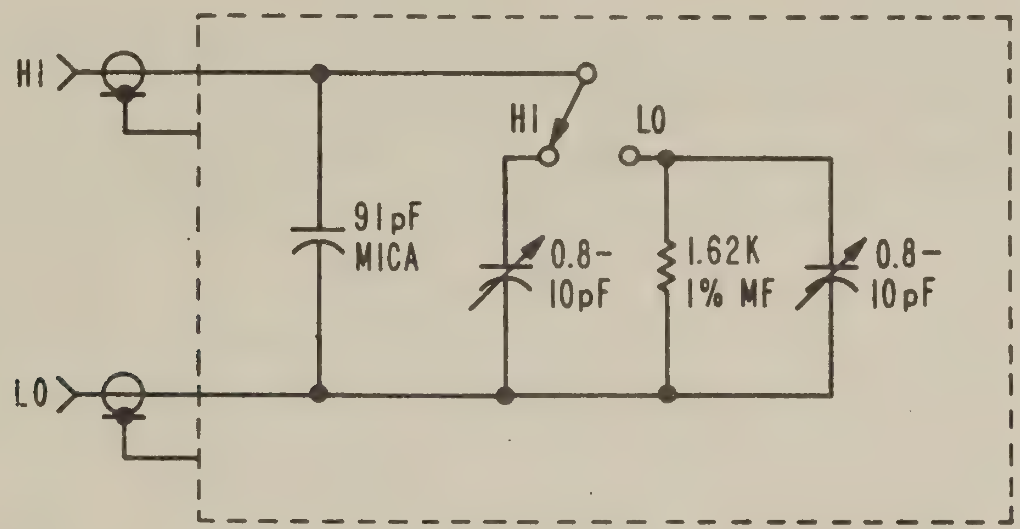
phase detector should be in correct phase relationship to the signal voltage through the amplifier.

This is established by checking the instrument with high and low Q capacitors as follows:

6.6.1 HI - LO Test

Set the instrument to the 100 pF range, zero, and connect HI-LO Q standard to the instrument. Make the capacitance measurement in HI and LO Q position of the standard and compare the results. If the results differ by more than 0.5%, HI-LO Q adjustments need readjusting.

If a HI-LO Q standard is not available, a simple substitute may be constructed as follows:



TRIMMER CAPACITORS SHOULD BE ADJUSTED IN BOTH SWITCH POSITIONS FOR A CAPACITANCE OF 100pF ± 0.5pF, AS MEASURED ON A 1MHz CAPACITANCE BRIDGE.

Figure 8. HI - LO Q Standard

6.6.2 HI - LO Q Adjustment

Set the instrument to the 100 pF (200 pF) range and zero with the front ZERO control. Connect a sensitive RF voltmeter to the test point TP3 and measure the RF voltage, which is typically 10 - 30 mV. Adjust the phase detector balance with C233 for minimum indication on the RF voltmeter.

Now connect a HI-LO capacitance standard to the test terminal and make a measurement in the HI-Q position. Record the result. Make the same measurement in the standard's LO-Q position and adjust C228 until the HI and LO Q measurements agree within 0.25%.

If the range of C228 is not sufficient to bring the indications into agreement, transformer T201 core may be adjusted for the same purpose.

HI-LO Q adjustment may require recalibration of the 100 pF range (see Section 6.4).

6.7 Input Transformer T401, C202 Tuning and Symmetry Adjustment

The input transformer should be tuned to the 1 MHz crystal for proper operation of the oscillator. This may be accomplished either by the trimmer C202 or by adjusting the transformer core. The core adjustment should be used only when there is evidence that the core has vibrated loose or the range of C202 is not sufficient for proper adjustment.

6.7.1 T401, C202 Adjustment

To adjust trimmer C202, remove the top cover and connect a VOM, 10 V range, to TP1 on the amplifier plug-in board. Adjust C202 for a maximum voltage on TP1, typically +7 to +12 V. If the maximum cannot be reached by adjusting C202, the core of transformer T401 may have shifted. To adjust the core, remove the test adapter and look for the adjustment hole between the upper banana terminals.

The core is normally fixed in its position either by a plastic lock nut or a small drop of Glyptol cement. If a lock nut is used, it may be unscrewed with a 1/8" wide blade screwdriver.

If no lock nut is used, the core may be adjusted directly with a 1/16" wide nonmetallic screwdriver. A drop of lacquer thinner applied to the core will loosen the core.

The core should be adjusted for maximum voltage on TP1, as described for the C202 adjustment.

After this adjustment, the instrument should be calibrated per Section 6.4.2.1.

6.7.2 Test Voltage Symmetry Adjustment

The single-turn secondary of transformer T401 has an adjustable center tap by which the test voltage on TEST and DIFF terminals may be adjusted to be equal. The equality of TEST and DIFF voltages is important when an external standard is connected to the DIFF terminals for differential measurements. Normally the TEST and DIFF voltages are adjusted to be equal within 0.25%.

To adjust the symmetry, remove the top and bottom covers. Connect an accurate dc digital voltmeter to TP2 on the oscillator amplifier plug-in card. Adjust the front ZERO for zero indication on the DVM.

Plug a 100 pF capacitance standard to TEST and DIFF terminals and observe the voltmeter indication. The voltmeter should indicate approximately +0.5 V at TEST terminal and -0.5 V at DIFF terminal. With a 1/16" wide blade screwdriver adjust T401 at the right side of the instrument until the magnitude of both indications is exactly equal.

6.8 1 MHz Amplifier Tuning (L201 Adjustment)

For accurate adjustment of L201, the 1 MHz amplifier should be operated without overall feedback by unsoldering the link between the two solder terminals next to the L201 coil. Now the amplifier gain is increased by approximately 30 dB and the frequency response is very sharply peaked at 1 MHz.

To adjust L201, set the instrument to the 100 pF range, connect an rf voltmeter to TP3, and adjust the "ZERO" control until an indication of 0.2 to 0.5 V is observed on the rf voltmeter. Now adjust the core of L201 with a 1/16" wide insulated screwdriver (from the rear of the amplifier PC board) to peak the voltmeter indication to maximum.

After adjustment, close the feedback loop by resoldering the link between the terminals. Test level adjustment per 6.4.2.1 is needed after the L201 adjustment is made.

CHAPTER VII

TROUBLESHOOTING PROCEDURE

In case of instrument failure or malfunction, a two-step approach to troubleshooting and repair is recommended:

a. Identify the defective section.

b. Troubleshoot and repair the section.

7.1 Identification of Defective Section

To identify a defective section use the troubleshooting diagram and the simplified troubleshooting schematic.

The instruments listed in Section 6.2 are also sufficient for troubleshooting.

The diagrams should be sufficient to guide you through a logical troubleshooting sequence. The only point for attention is TP2 - the input to the 1 MHz amplifier. Under normal operating conditions the signal level at this point is 150 µV at 1 MHz for a full scale indication on every "1" range. This signal is too low to be measured with the recommended instrumentation. Therefore, introduce a 10 times overload (100 pF test capacitor on the 10 pF range) to bring this level to a measurable range, for testing ranging circuitry.

7.2 Troubleshooting Defective Sections

The simplified troubleshooting schematic E830715 should be used to find the pertinent signal and dc voltage levels. This information together with specific tests recommended in the following section should enable an experienced troubleshooter to locate and repair defective components.

7.2.1 Power Supply

Normal output level:

+15 V supply at +C128: +15 V ±0.25 V

-15 V supply at -C129: -15 V ±0.25 V

When the output voltage cannot be set to the specified limit, check for an external short by checking the temperature of the series regulators (IC101, 102, and 103). High temperatures

indicate external shorts; a cool regulator indicates trouble in the power supply or normal operation.

7.2.2 1 MHz Oscillator

Normal operating level

at LO terminal: 1 MHz, 15 mV ±2 mV

at TP1: +7.5 to 12 V dc

at J101 pin X: 3.4 V rms, 1 MHz

Check C202 or T401 tuning (6.7.1). When grossly out of tune, the oscillator will not oscillate.

7.2.3 Ranging Circuitry

Ranges are selected by reed relays K101 to K103 and switching diodes CR109 to CR112. If a particular range is activated, that reed relay is closed and its associated switching diode is forward biased.

Normal voltages levels are as follows:

	Pin 3 or 5 if IC106 or IC107	Pin D of J101
Range activated	0 V	4.2 V
Range not activated	+20 V	4.2 V

If IC106 or IC107 pin 3 or 5 voltage is pulled down when selecting the proper range but the range is not activated properly, look for trouble in the reed relays, switching diodes (CR109 to CR112) and associated circuitry.

If pin 3 or 5 voltage is not pulled down by range selection, the trouble is in the range switch, ranging lines, or IC106 and 107 packages.

"3" ranges are selected by decreasing indicator M101 current by opening K104 contact.

7.2.4 1 MHz Amplifier

The amplifier is a tuned feedback amplifier with closed loop gain of approximately 70 dB. The open loop gains by stages are:

First Stage (Q203 and Q204): 54 dB

Second Stage (Q205): 23 dB

Third Stage (Q207): 23 dB

Output level of 0.5 V at TP3 is produced by input level of 150 μV at pin D of J101, which is too low to measure with normal instrumentation.

To troubleshoot the amplifier, check dc operating points and signal levels per the troubleshooting schematic E830715. Replace defective components, if needed. If this does not restore normal gain, check L201 tuning per Section 6.8.

The condition where the instrument operates normally in one or several ranges indicates that the trouble is in the ranging circuitry. The amplifier should not be serviced in this case.

7.2.5 Phase Sensitive Detector

The phase sensitive detector circuitry consists of bridge circuit CR205 to CR208 and overload detector Q208 and Q209. Normal operating levels at full scale (100 pF on 100 or 200 pF range) are:

1 MHz amplifier output TP3: 500 mV, 1 MHz
Detector output at TP2: +0.5 V dc
Phase reference drive at C228: 10 V, 1 MHz

When the instrument is zeroed, the phase detector output at TP2 should be 0 mV.

Normal overload sensor voltage on pin S, J101 is -15 V when indication is on range (1 MHz amplifier output at TP3 of up to 1.5 V, 1 MHz). With an overload condition (TP3 voltage above 1.8 V), the pin S voltage should change to +12 V.

7.2.6 Phase Reference Channel

The phase reference channel consists of reference amplifier Q206 and divider and phase shifting network. Normal operating levels are:

Input (Q206 base): 4.8 V, 1 MHz
Output at T201 secondary: 10 V, 1 MHz

T201 is tuned for maximum output at 1 MHz and finally adjusted for correct phase per Section 6.6.

7.2.7 Output Amplifier

Operational amplifier A101 drives the meter circuit and analog output. Normal operating level with 100 pF at the 100 pF (200 pF) range:

Input at pin 3: 0.5 V

Output at pin 5: 1.0 V

An overload signal causes the amplifier to clamp to a maximum positive output; the overload signal is then applied to pin 8, whose normal voltage (up to 1.5 V at pin 3) is 0 and whose overloaded voltage (above 1.8 V at pin 3) is up to +12 V.

The input and output voltage of the Model 72B output amplifier will be zero if there is zero input to the Model 72B and the instrument is properly zeroed.

EXTERNAL PIN ASSIGNMENTS

TERMINAL	FUNCTION	REMARKS
A	+15 V	Power for BEC supplied options only
B	+5 V	Power for BEC supplied options only
1	±HI TERMINAL BIAS	±200 V dc max.
2	±LO TERMINAL BIAS	±400 V dc max.
3	GND	
4	+ ANALOG OUTPUT	+1 V fs 1-10-100-1000 range +3 V fs 3-30-300-3000 range $Z \approx 1$ kΩ
5	GND	
7	MANUAL DISABLE	Connect to GND to disable front panel programming.
9	3000 pF RANGE	External range programming inputs
10	1000 pF RANGE	Logic 0 or connection to common selects
11	300 pF RANGE	corresponding range. These lines may be
12	100 pF RANGE	used as outputs to indicate current opera-
13	30 pF RANGE	ting range: the range line corresponding
14	10 pF RANGE	to the operating range will be at logic
15	3 pF RANGE	0 (logic 0 < +0.5 V)
16	1 pF RANGE	

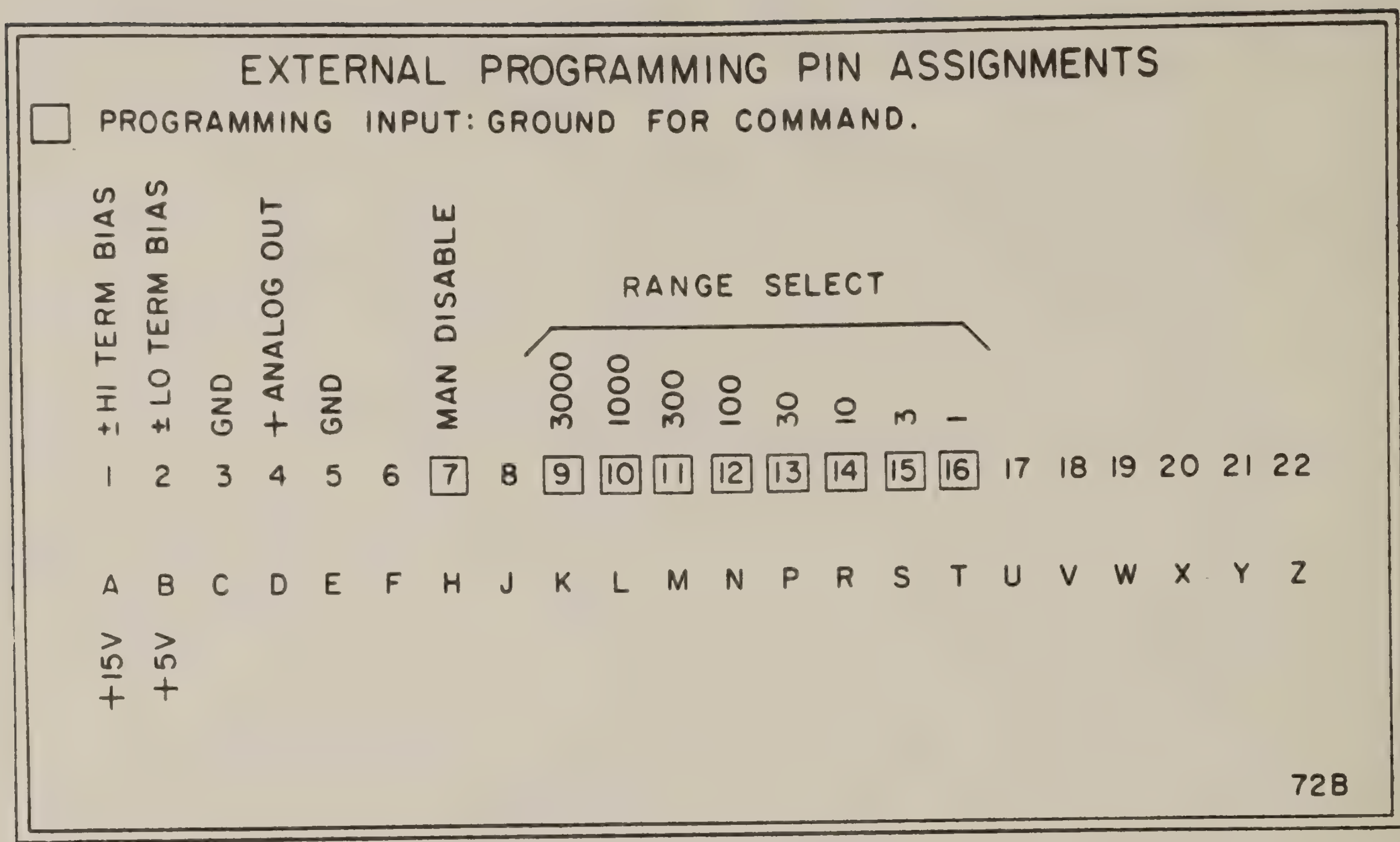


Figure 9. External Connections

TABLE OF REPLACEABLE PARTS

Reference		Description	BEC Part No.
		MASTER BOARD	
A101	Op. Amp.	LM301AN	535012
C101	Capacitor, PC	0.1 μF 10% 630 V	234091
C102	Capacitor, PC	0.15 μF 10% 630 V	234147
C103	Capacitor, Mica	82 pF 1% 500 V	200107
C104	Capacitor, Mica	100 pF 5% 500 V	200001
C105	Capacitor, Mica	910 pF 1% 100 V	200075
C106	Capacitor, Mica	0.01 μF 1% 300 V	203017
C107	Capacitor, Mica	5 pF ±1 pF 500 V (factory Selected) AND/OR	200043
C107	Capacitor, Mica	10 pF 5% 500 V (Factory Selected)	200022
C108	Capacitor, Elec.	250 μF 40 V	283207
C109	Capacitor, Elec.	250 μF 50 V	283207
C110	Not Used		
C111	Capacitor, Var.	2 - 6 pF red	281015
C112	Capacitor, Mica	68 pF 5% 500 V	200031
C113	Capacitor, Mica	82 pF 1% 500 V	200107
C114	Capacitor, Mica	680 pF 1% 300 V	200015
C115	Capacitor, Cer.	0.001 μF 500 V	224114
C116	Capacitor, PE	0.1 μF 10% 100 V	234080
C117	Capacitor, Var.	5.1 - 50 pF green	281006
C118	Capacitor, PE	0.1 μF 10% 100 V	234080
C119	Capacitor, Cer.	0.001 μF 500 V	224114
C120	Capacitor, PE	0.1 μF 10% 100 V	234080
C121	Capacitor, Var.	5.1 - 50 pF green	281006
C122	Capacitor, PE	0.1 μF 10% 100 V	234080
C123	Capacitor, Cer.	0.001 μF GMV 500 V	224114
C124	Capacitor, Cer.	0.001 μF GMV 500 V	224114
C125	Capacitor, Cer.	0.001 μF GMV 500 V	224114
C126	Not Used		
C127	Capacitor, PE	0.1 μF 10% 100 V	234080
C128	Capacitor, Elec.	100 μF +75/-10% 25 V	283105
C129	Capacitor, Elec.	100 μF +75/-10% 25 V	283105
C130	Capacitor, Mica	30 pF 5% 500 V	200073
C131	Capacitor, PE	0.1 μF 10% 100 V	234080
C132	Capacitor, PE	0.022 μF 20% 250 V	234079
C133	Not Used		
C134	Capacitor, Mica	3 pF ±0.5 pF 300 V OR Selected	205013
C134	Capacitor, Mica	5 pF 10% 300 V	205000
C135			
C136	Capacitor, Cer	1.0 μF 20% 50 V	224264
CR101	Diode, Sig.	1N914	530058
CR102	Diode, Sig.	1N914	530058
CR103	Diode, Sig.	1N914	530058
CR104	Diode, BR	KBP-02	532013
CR105	Diode, BR	KBP-02	532013
CR106	Not Used		
CR107 through CR112	Diode, Sig.	1N914	530058
CR113	Diode, Zener	1N5230B (4.7 V)	530103
CR114	Diode, Sig.	1N914	530058
CR115	Diode, Sig.	1N914	530058
IC101	Integrated Circuit	μA7805UC (Voltage Regulator)	535011
IC102	Integrated Circuit	μA7805UC (Voltage Regulator)	535011

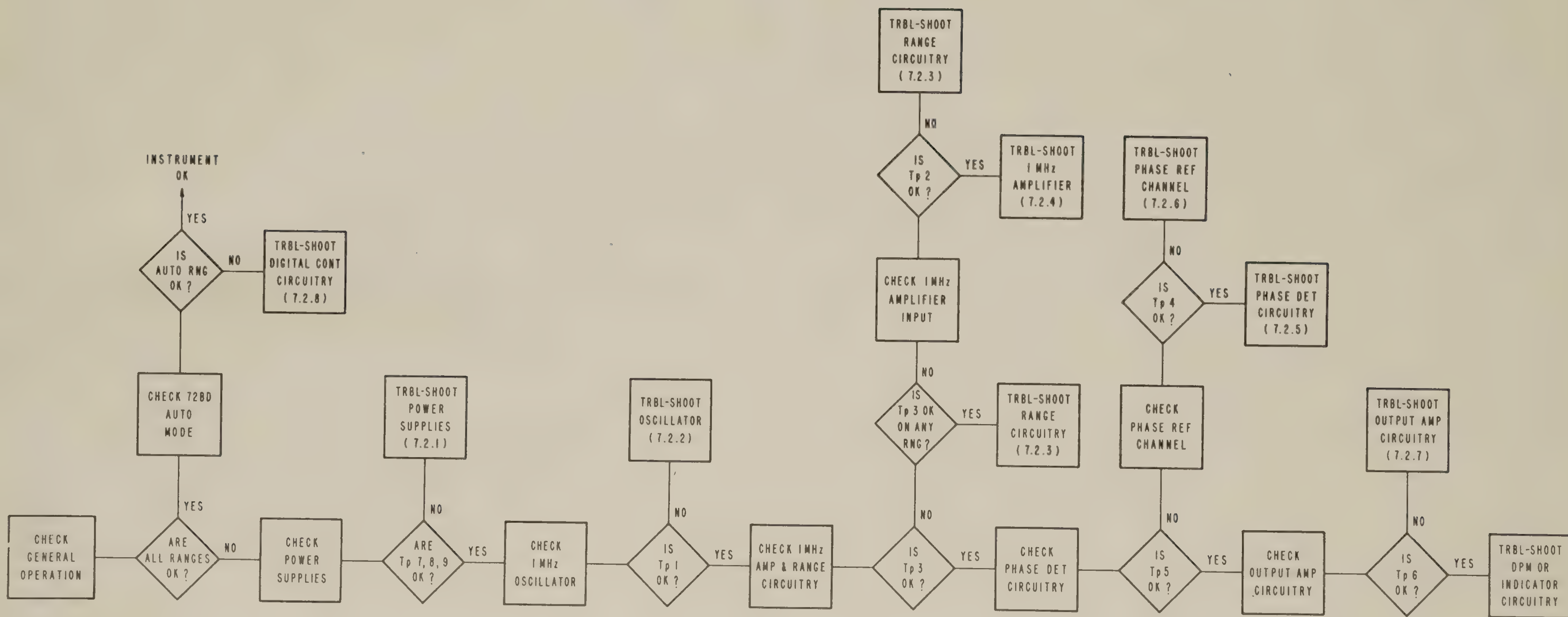
Reference		Description	BEC Part No.
		MASTER BOARD (CONTINUED)	
IC103	Not Used		
IC104	Integrated Circuit	LM723CN (Voltage Regulator)	535037
IC105	Integrated Circuit	LM723CN (Voltage Regulator)	535037
IC106	Integrated Circuit	SN75451AP (Interface Circuit)	534006
IC107	Integrated Circuit	SN75451AP (Interface Circuit)	534006
IC108	Integrated Circuit	SN75451AP (Interface Circuit)	534006
IC109	Not Used		
IC110	Integrated Circuit	N8471A (Input NAND Gate)	534005
J101	Connector, PC	Amphenol 143-022-03 (22 Pin)	479231
K101 through K104	Relay, Reed	Gordos No. MR307	471000
L101	Choke	560 μH 5%	400183
L102	Coil	28 - 60 μH	400377
L103	Coil	14 - 28 μH	400231
L104	Coil	1.5 - 3 μH	400232
L105	Choke	4.7 μH 10%	400113
L106 through L111	Choke	2.2 mH 10%	400141
L112	Coil	220 μH 5%	400319
R101	Not Used		
R102	Not Used		
R103	Resistor, Comp.	1.3 kΩ 5%	344311
R104	Resistor, Comp.	100 kΩ 5%	344500
R105	Resistor, Comp.	100 kΩ 5%	344500
R106	Resistor, Comp.	5.1 kΩ 5%	344368
R107	Resistor, Comp.	1 kΩ 5%	343300
R108	Resistor, Comp.	1 kΩ 5%	343300
R109	Resistor, Comp.	2 kΩ 5%	344329
R110 through R113	Resistor, Comp.	10 kΩ 5%	344400
R114	Resistor, MF	3.32 kΩ 1%	341350
R115	Resistor, Var.	1 kΩ 10% 1/2 W	311316
R116	Resistor, MF	3.01 kΩ 1%	341346
R117	Resistor, MF	3.32 kΩ 1%	341350
R118	Resistor, Var.	1 kΩ 10% 1/2 W	311316
R119	Resistor, MF	3.01 kΩ 1%	341346
R120	Resistor, Comp.	1.2 kΩ 5%	344308
R121	Resistor, Comp.	3.9 kΩ 5%	343357
R122	Resistor, Comp.	3.9 kΩ 5%	343357
R123	Resistor, Comp.	3.9 kΩ 5%	343357
R124 through R131	Resistor, Comp.	5.1 kΩ 5%	343368
R132	Resistor, MF	10 kΩ 1%	341400
R133	Resistor, Var.	20 kΩ 10% 1 W	311266
R134	Resistor, Comp.	4.7 MΩ 5%	344665
R135	Resistor, Comp.	10 MΩ 5%	343700
R136	Not Used		
R137	Resistor, Comp.	10 kΩ 5%	344400
R138	Resistor, MF	63.4 kΩ 1%	341477

Reference		Description	BEC Part No.
		MASTER BOARD (CONTINUED)	
R139	Resistor, MF	10 kΩ 1%	341400
R140	Resistor, MF	3.65 kΩ 1%	341354
R141	Resistor, MF	26.1 kΩ 1%	341440
R142	Resistor, Var.	5 kΩ 10% 1 W	311268
R143	Resistor, Comp.	1.3 kΩ 5%	344311
R144	Resistor, Var.	200 Ω 10% 1 W	311269
R145	Resistor, MF	54.9 kΩ 1%	341471
R146	Resistor, Var.	5 kΩ 10% 1 W	311268
R147	Resistor, MF	1.21 kΩ 1%	341308
R148	Resistor, Comp.	4.7 kΩ 5%	344365
R149	Resistor, Comp.	1.8 kΩ 5%	343325
R150	Resistor, Comp.	1.8 kΩ 5%	343325
		OSCILLATOR/AMPLIFIER BOARD	
A201	Op. Amp.	LM301AN	535012
C201	Capacitor, Cer.	0.001 µF GMV 500 V	224114
C202	Capacitor, Var.	5.1 - 50 pF Green	281006
C203	Capacitor, Elec.	33 µF 20% 15 V	283206
C204	Capacitor, Cer.	0.001 µF GMV 500 V	224114
C205	Capacitor, PE	0.1 µF 10% 100 V	234080
C206	Capacitor, Cer.	0.001 µF GMV 500 V	224114
C207	Capacitor, PE	0.1 µF 10% 100 V	234080
C208	Capacitor, Elec.	33 µF 20% 15 V	283206
C209	Capacitor, Mica	250 pF 5% 500 V	200036
C210	Capacitor, Mica	30 pF 5% 500 V	200073
C211	Capacitor, Cer.	0.01 µF 100 V	224119
C212	Capacitor, PE	0.1 µF 10% 100 V	234080
C213	Capacitor, Mica	160 pF 5% 500 V	200048
C214	Capacitor, Mica	82 pF 5% 500 V	200074
C215	Capacitor, PE	0.1 µF 10% 100 V	234080
C216	Capacitor, Cer.	0.001 µF GMV 500 V	224114
C217	Capacitor, PE	0.1 µF 10% 100 V	234080
C218	Capacitor, Mica	39 pF 5% 500 V	200025
C219	Capacitor, Mica	39 pF 5% 500 V	200025
C220	Capacitor, Cer.	0.001 µF GMV 500 V	224114
C221 through C227	Capacitor, PE	0.1 µF 10% 100 V	234080
C228	Capacitor, Var.	2.5 - 20 pF Blue	281005
C229	Capacitor, PE	0.1 µF 10% 100 V	234080
C230	Capacitor, Mica	680 pF 1% 300 V	200015
C231	Capacitor, Mica	680 pF 1% 300 V	200015
C232	Capacitor, Mica	39 pF 5% 500 V	200025
C233	Capacitor, Var.	5.1 - 50 pF Green	281006
C234	Capacitor, PE	0.022 µF 20% 250 V	234079
C235	Capacitor, PE	0.022 µF 20% 250 V	234079
C236	Capacitor, Cer.	0.001 µF GMV 500 V	224114
C237	Capacitor, PE	0.022 µF 20% 250 V	234079
C238	Capacitor, PE	0.022 µF 20% 250 V	234079
C239	Capacitor, Cer.	0.01 µF 100 V	224119
C240	Not Used		
C241	Not Used		
C242	Not Used		
C243*	Capacitor, Mica	39 pF 5% 300 V	205044
C243*	Capacitor, Mica	56 pF 5% 300 V	205031

Reference		Description	BEC Part No.
		OSCILLATOR/AMPLIFIER BOARD (CONTINUED)	
C243*	Capacitor, Mica	75 pF 5% 300 V	205043
C243*	Capacitor, Mica	100 pF 5% 300 V	205006
C243*	Capacitor, Mica	130 pF 5% 100 V	205011
C243*	Capacitor, Mica	150 pF 5% 100 V	205009
*One of the above selected.			
CR201	Diode, Sil.	1N914	530058
CR202	Diode, Zener	1N5240B (10 V)	530077
CR203	Diode, Sil.	1N914	530058
CR204	Diode, Sil.	1N914	530058
CR205 through CR208	Dilde, Sil.	Factory Selected	530131
CR209 through CR212	Diode, Sil.	1N914	530058
L201	Inductor Var. Unit	Boonton Electronics	062009-1
L202	Choke	2.2 mH 10%	400141
L203	Choke	2.2 mH 10%	400141
L204	Choke	2.2 mH 10%	400141
Q201	Transistor, FET	TIS58	528038
Q202	Transistor, FET	2N5949	528019
Q203	Transistor, FET	TIS58	528038
Q204	Transistor, NPN	2N5088	528047
Q205	Transistor, FET	40673 Blue (Selected)	528119
Q206	Transistor, NPN	2N2219	528014
Q207	Transistor, FET	40673 Blue (Selected)	528119
Q208	Transistor, PNP	2N3905	528025
Q209	Transistor, FET	3N161	528132
R201	Resistor, MF	1.21 kΩ 1%	341308
R202	Resistor, Var.	2 kΩ 10% 1 W	311264
R203	Resistor, MF	8.25 kΩ 1%	341388
R204	Resistor, MF	4.32 kΩ 1%	341361
R205	Resistor, MF	33.2 kΩ 1%	341450
R206	Resistor, Comp.	100 kΩ 5%	344500
R207	Resistor, MF	100 kΩ 1%	341500
R208	Resistor, Comp.	12 kΩ 5%	344408
R209	Resistor, Comp.	6.8 kΩ 5%	344380
R210	Resistor, Comp.	560 kΩ 5%	344572
R211	Resistor, Comp.	33 Ω 5%	344150
R212	Resistor, Comp.	1 kΩ 5%	344300
R213	Resistor, MF	10 Ω 1%	341100
R214	Resistor, Comp.	150 kΩ 5%	344517
R215	Resistor, Comp.	100 kΩ 5%	344500
R216	Resistor, Comp.	2.7 kΩ 5%	344341
R217	Resistor, Comp.	1 kΩ 5%	344300
R218	Resistor, MF	590 Ω 1%	341274
R219	Resistor, Comp.	6.2 kΩ 5%	344376
R220	Resistor, Comp.	3.9 kΩ 5%	344357
R221	Resistor, Comp.	120 kΩ 5%	344508
R222	Resistor, Comp.	47 kΩ 5%	344465
R223	Resistor, Comp.	2.2 MΩ 5%	344633
R224	Resistor, Comp.	510 Ω 5%	344268
R225	Not Used		
R226	Resistor, Comp.	270 Ω 5%	344241
R227	Resistor, Comp.	47 Ω 5%	344165

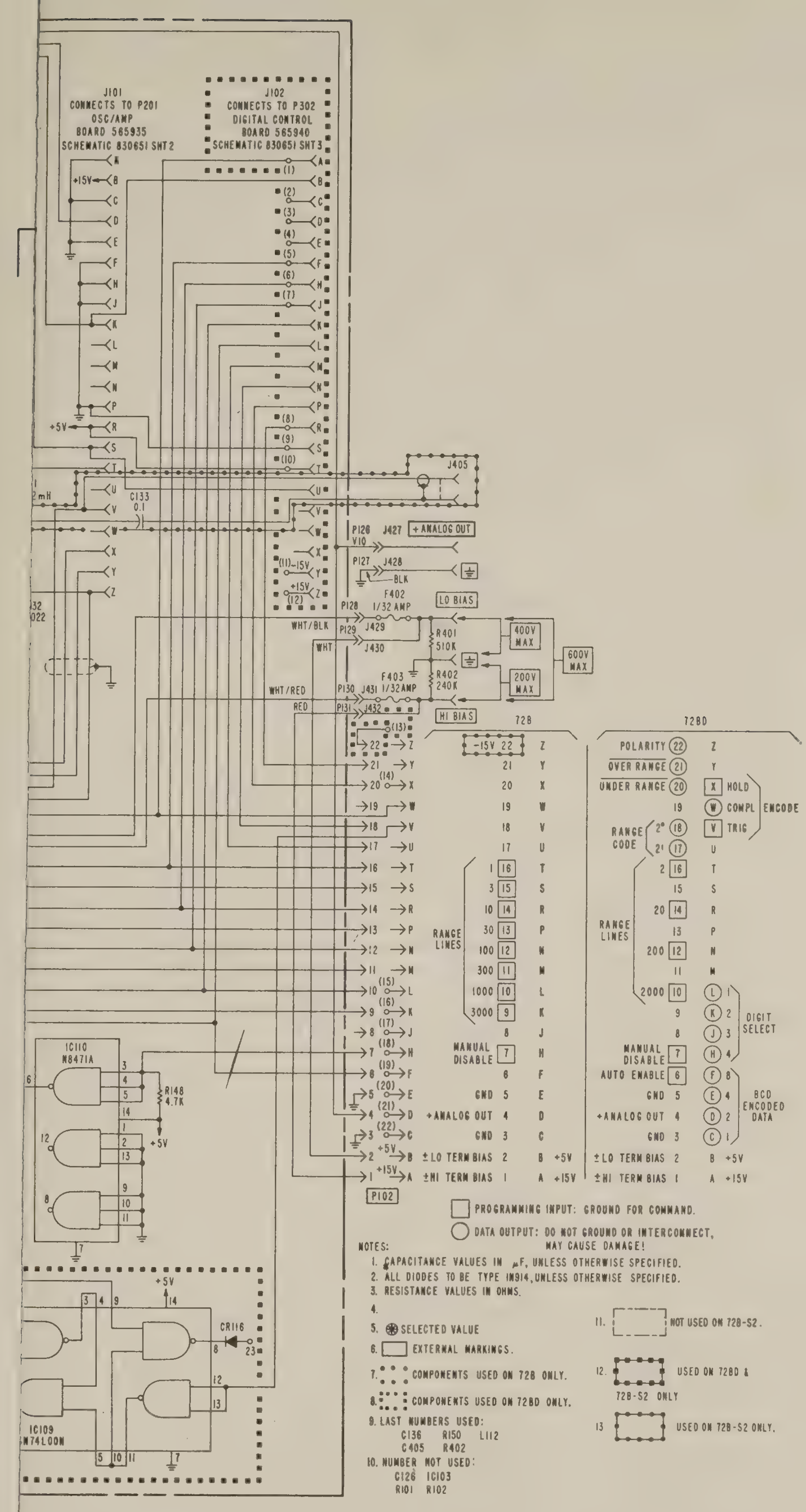
Reference	Description			BEC Part No.
	OSCILLATOR/AMPLIFIER BOARD (CONTINUED)			
R228	Resistor, Comp.	56 Ω 5%		344172
R229	Resistor, Comp.	47 kΩ 5%		344465
R230	Resistor, Comp.	2.4 kΩ 5%		344337
R231	Resistor, Comp.	1.5 kΩ 5%		344317
R232	Resistor, Comp.	100 Ω 5%		344200
R233	Resistor, Comp.	12 kΩ 5%		344408
R234	Resistor, MF	2.67 kΩ 1%		341341
R235	Resistor, MF	49.9 Ω 1%		341167
R236	Resistor, Comp.	2 kΩ 5%		344329
R237	Resistor, Comp.	2.7 kΩ 5%		344341
R238	Resistor, MF	Factory Selected		325399
R239	Resistor, MF	Factory Selected		325399
R240	Resistor, Comp.	10 MΩ 5%		344700
R241	Resistor, MF	Factory Selected		325399
R242	Resistor, Var.	100 Ω 10% 1 W		311338
R243	Resistor, MF	Factory Selected		325399
R244	Resistor, Comp.	10 kΩ 5%		343400
R245	Resistor, Comp.	47 kΩ 5%		344465
R246	Resistor, Comp.	100 Ω 5%		343200
R247	Resistor, MF	10.0 kΩ 1%		341400
RT201	Thermistor	50 Ω 10%		325011
T201	Transformer, Phase Sens. Det. Unit		Boonton Electronics	062011-1
T202	Transformer, Amp. Output Unit		Boonton Electronics	062010-1
Y201	Crystal	1 MHz 0.1%		547029
	FRONT SUB PANEL			
C404	Capacitor, Var.	1.8 - 8.7 pF		275138
M101	Meter, Analog	API		554249
S401, DS401	Switch/On/Off & Pilot Light		UID Electronics	465165
S403	Switch, Rotary	Ledex Series 208		466214
T401	Oscillator Transformer Assembly		Boonton Electronics	072006-3
	OSCILLATOR TRANSFORMER			
C401	Capacitor, Mica	560 pF 1% 300 V		200091
	REAR PANEL			
C402	Capacitor, Cer.	0.01 μF 20% 1000 V		224228
C403	Capacitor, Cer.	0.01 μF 20% 1000 V		224228
F401	Fuse	0.2 A (120 V)		545508
F401	Fuse	0.1 A (240 V)		545519
F402	Fuse	1/32 A 250 V AGC		545525
F403	Fuse	1/32 A 250 V AGC		545525

Reference		Description	BEC Part No.
		REAR PANEL (CONTINUED)	
P401	Connector, Line Cord	Belden No. 17252	477281
R401	Resistor, Comp.	510 kΩ 5%	344568
R402	Resistor, Comp.	240 kΩ 5%	344537
S402	Switch, Rotary	Ledex Series 210	466230
T402	Power Transformer	Boonton Electronics	446071



BOONTON ELECTRONICS CORPORATION

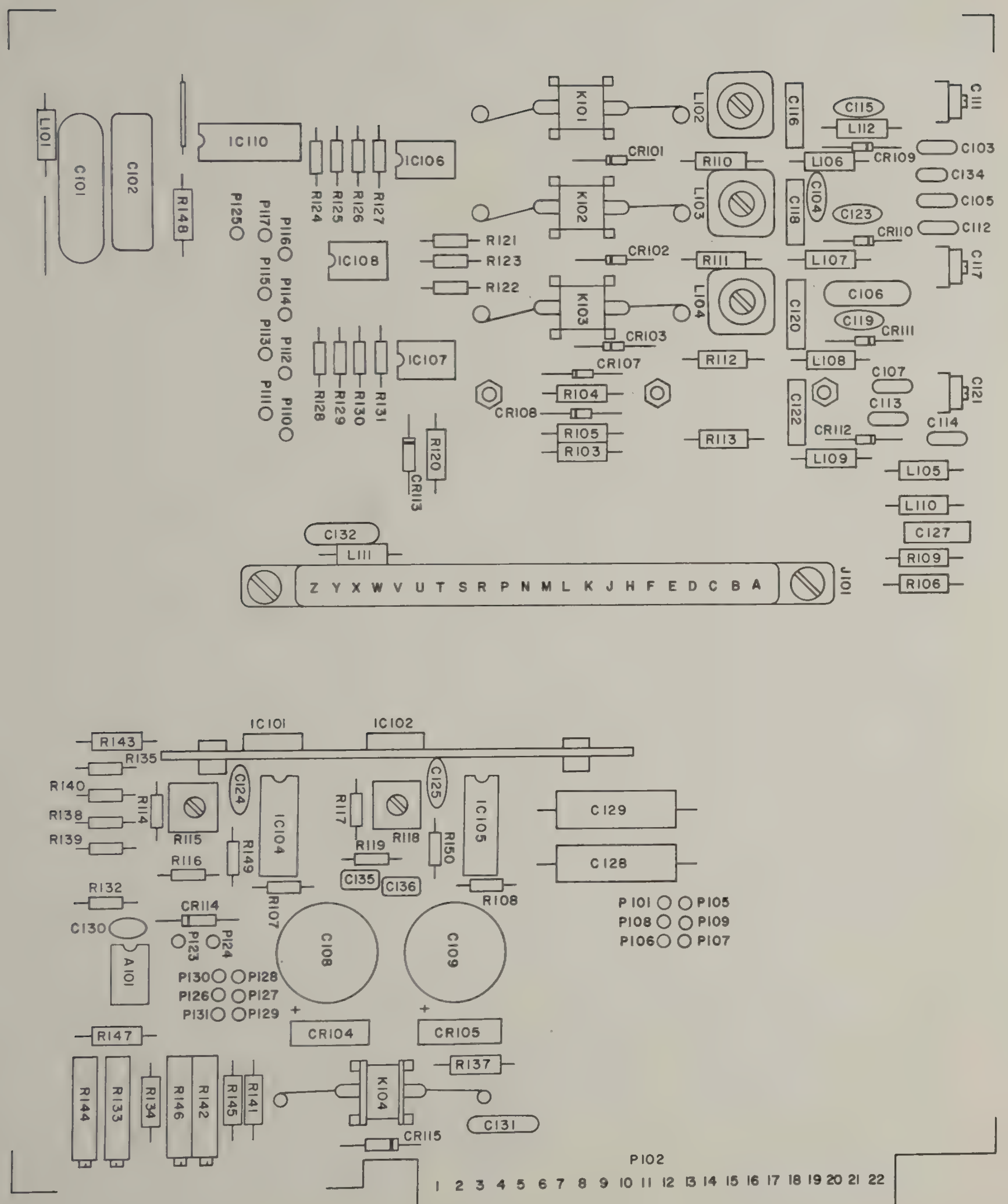
MODEL 72B, 72BD
BLOCK DIAGRAM,
Trouble Shooting
D830716A

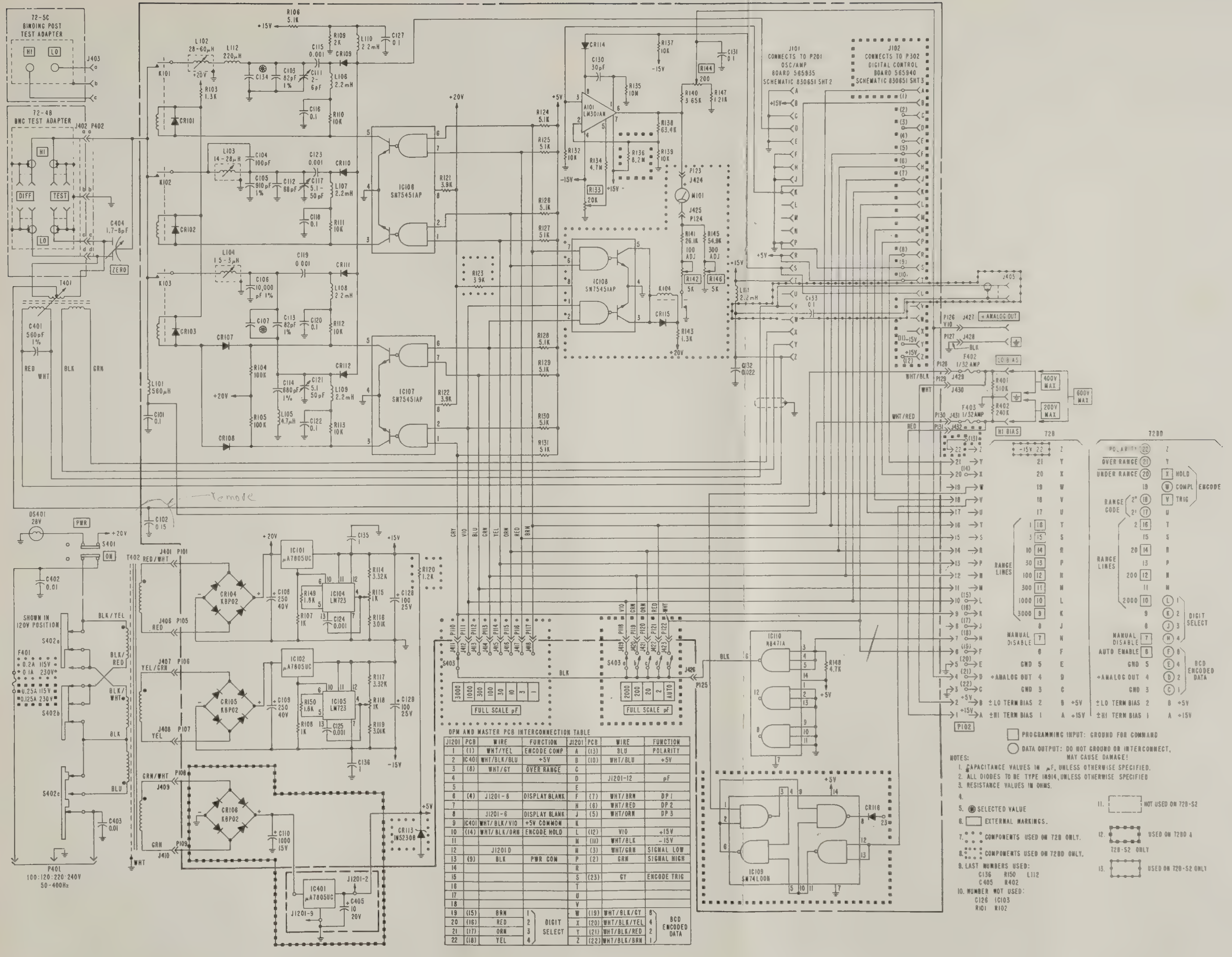


COMPONENT NUMBERS
100 SERIES

BOONTON ELECTRONICS CORPORATION

MODEL 72B, 72BD
Schematic, Master
E830651N Sht. 1 of 3





DPM AND MASTER PCB INTERCONNECTION TABLE

J1201	PCB	WIRE	FUNCTION	J1201	PCB	WIRE	FUNCTION
1	(1)	WHT/YEL	ENCODE COMP	A	(13)	BLU	POLARITY
2	IC401	WHT/BLK/BLU	+5V	B	(10)	WHT/BLU	+5V
3	(8)	WHT/GY	OVER RANGE	C			
4				D		J1201-12	pF
5				E			
6	(4)	J1201-8	DISPLAY BLANK	F	(7)	WHT/BRN	DP 1
7				H	(6)	WHT/RED	DP 2
8		J1201-6	DISPLAY BLANK	J	(5)	WHT/ORN	DP 3
9	IC401	WHT/BLK/VIO	+5V COMMON	K			
10	(14)	WHT/BLK/ORN	ENCODE HOLD	L	(12)	VIO	+15V
11				M	(11)	WHT/BLK	-15V
12		J1201D		N	(3)	WHT/GRN	SIGNAL LOW
13	(9)	BLK	PWR COM	P	(2)	GRN	SIGNAL HIGH
14				R			
15				S	(23)	GY	ENCODE TRIG
16				T			
17				U			
18				V			
19	(15)	BRN	1 DIGIT SELECT	W	(19)	WHT/BLK/GY	8 BCD ENCODED DATA
20	(16)	RED	2	X	(20)	WHT/BLK/YEL	4
21	(17)	ORN	3	Y	(21)	WHT/BLK/RED	2
22	(18)	YEL	4	Z	(22)	WHT/BLK/BRN	1

PROGRAMMING INPUT: GROUND FOR COMMAND

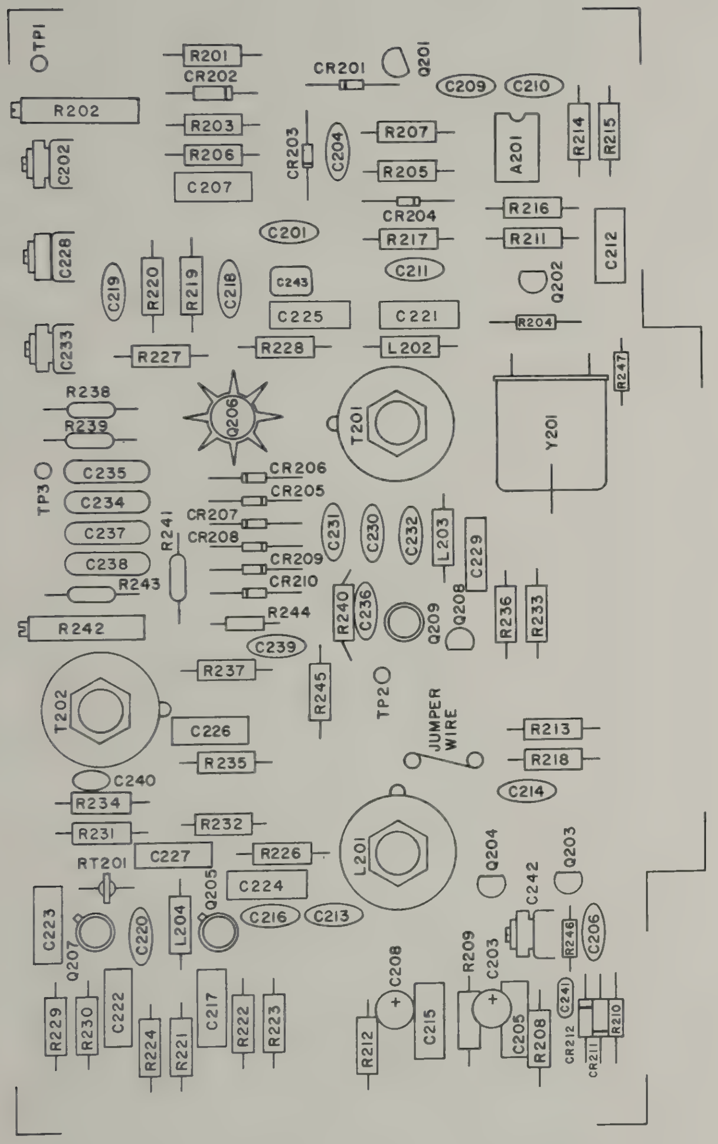
DATA OUTPUT: DO NOT GROUND OR INTERCONNECT, MAY CAUSE DAMAGE!

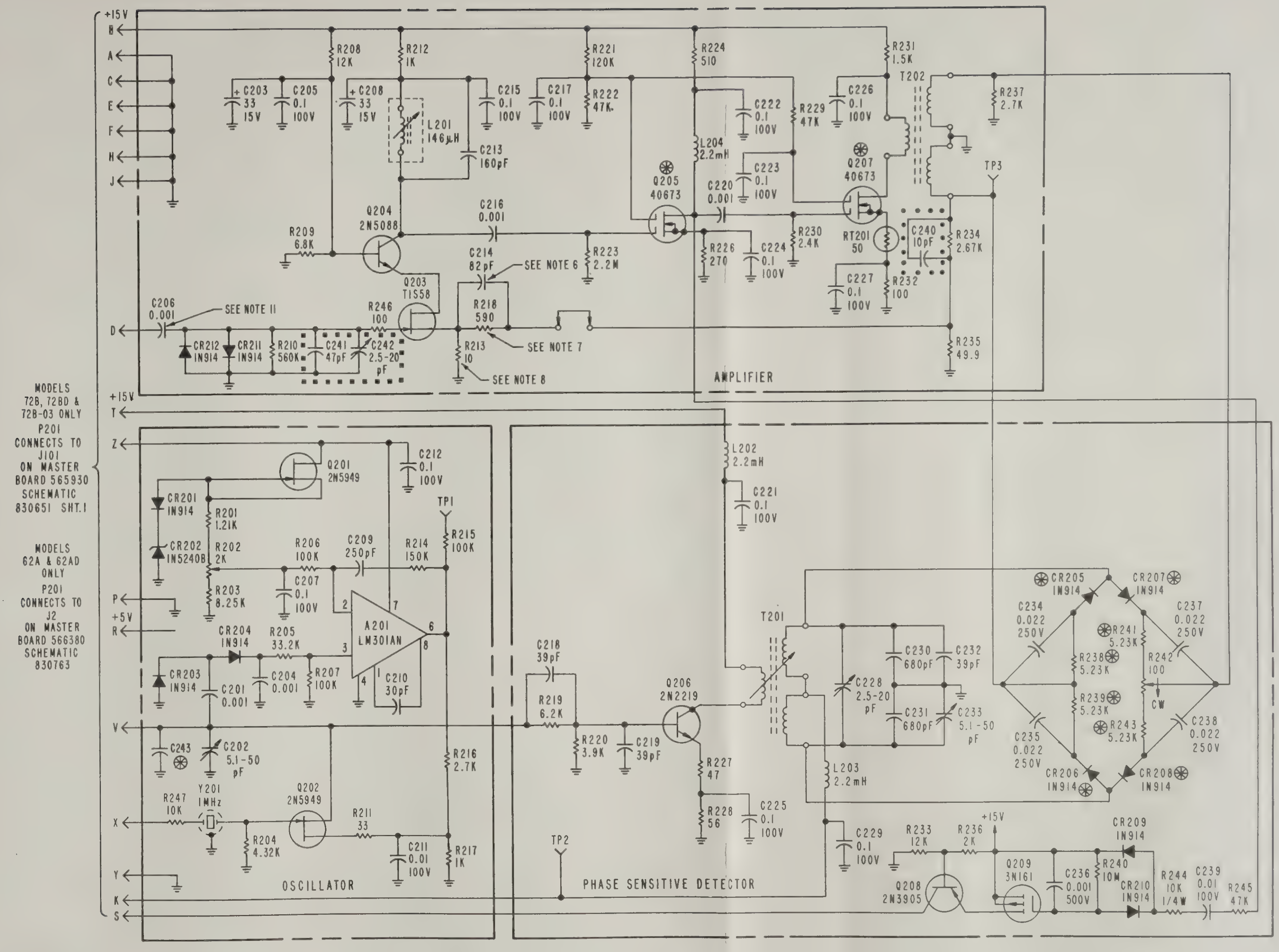
NOTES:
1. CAPACITANCE VALUES IN µF, UNLESS OTHERWISE SPECIFIED.
2. ALL DIODES TO BE TYPE 1N914, UNLESS OTHERWISE SPECIFIED
3. RESISTANCE VALUES IN OHMS.
4.
5. SELECTED VALUE
6. EXTERNAL MARKINGS.
7. COMPONENTS USED ON 72B ONLY.
8. COMPONENTS USED ON 72BD ONLY.
9. LAST NUMBERS USED: C136 R150 L112 C405 R402
10. NUMBER NOT USED: C126 IC103 R101 R102
11. NOT USED ON 72B-S2
12. USED ON 72BD & 72B-S2 ONLY
13. USED ON 72B-S2 ONLY

COMPONENT NUMBERS
100 SERIES

BOONTON ELECTRONICS CORPORATION

MODEL 72B, 72BD
Schematic, Master
E830651N Sht. 1 of 3





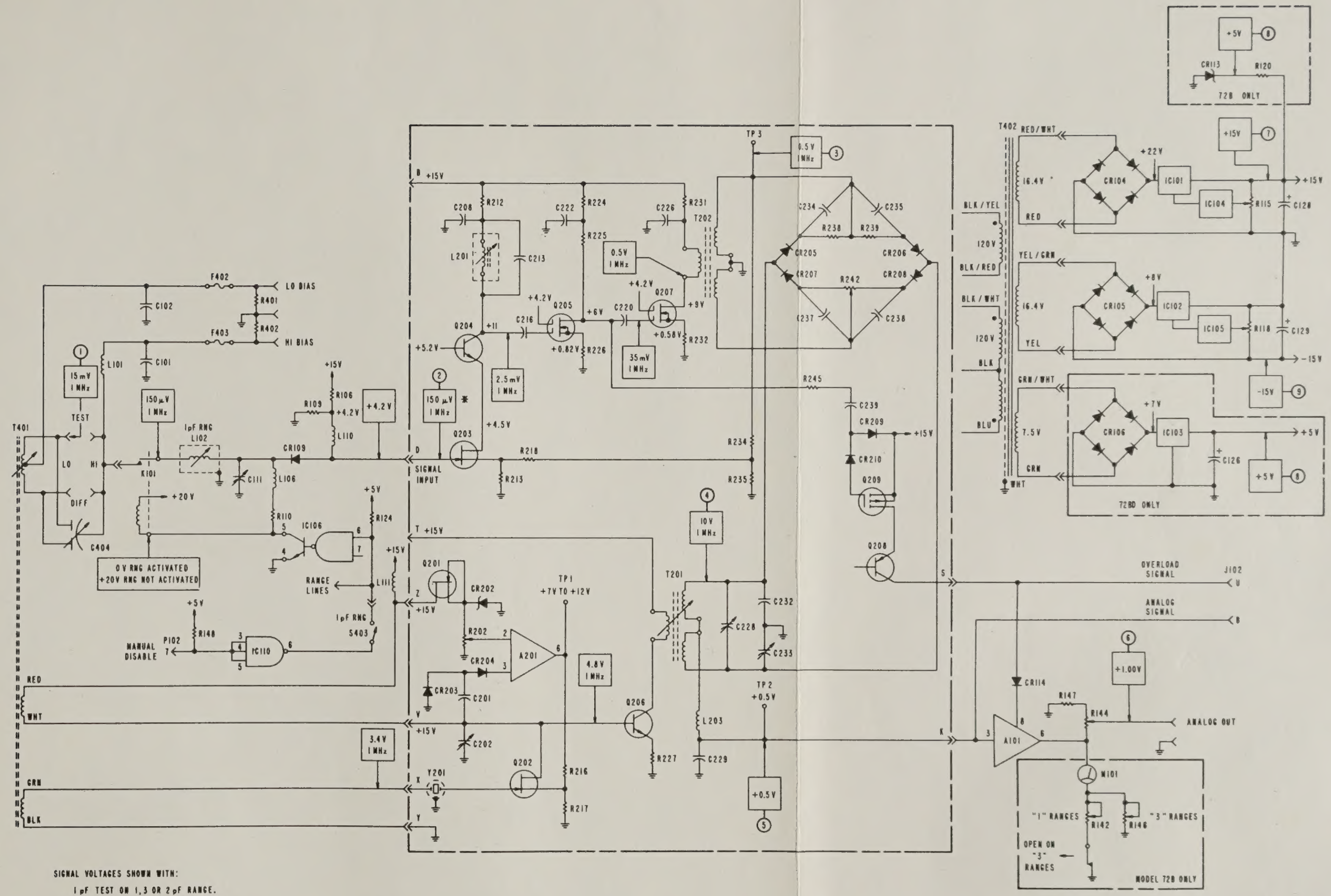
NOTES:

1. CAPACITANCE VALUES IN µF, UNLESS OTHERWISE SPECIFIED.
2. RESISTANCE VALUES IN OHMS.
3.
4. ⊛ SELECTED VALUE.
5. LAST NUMBERS USED: R247 C243 CR212 Q209
6. ON 62A, 62AD & 72B-SI-03 THIS VALUE IS 430pF.
7. ON 62A, 62AD & 72B-SI-03 THIS VALUE IS 60.4.
8. ON 62A, 62AD & 72B-SI-03 THIS VALUE IS 13.
9. SIGNIFIES COMPONENT ADDED FOR 62A, 62AD & 72B-SI-03.
10.
11. ON 72B-03 THIS VALUE IS 10pF.
12. SIGNIFIES COMPONENTS ADDED FOR 72B-03.

COMPONENT NUMBERS
200 SERIES

BOONTON ELECTRONICS CORPORATION

72B,B-03,B-S1-03,72BD,62A,AD
Schematic, Osc./Amp.
D830651T Sheet 2 of 3



SIGNAL VOLTAGES SHOWN WITH:

1 pF TEST ON 1,3 OR 2 pF RANGE.
10 pF TEST ON 10,30 OR 20 pF RANGE.
100 pF TEST ON 100, 300 OR 200 pF RANGE.
1000 pF TEST ON 1000, 3000 OR 2000 pF RANGE.
* TEST POINT 2 TEST 100 pF ON 10 (20 pF) RANGE.

BOONTON ELECTRONICS CORPORATION

MODEL 72B, 72BD
Schematic Trouble Shoot
E830715

WARRANTY

Boonton Electronics Corporation warrants its products to the original purchaser to be free from defects in material and workmanship and to operate within applicable specifications for a period of one year from date of shipment, provided they are used under normal operating conditions. This warranty does not apply to active devices that have given normal service, to sealed assemblies which have been opened or to any item which has been repaired or altered without our authorization.

We will repair, or at our option, replace any of our products which are found to be defective under the terms of this warranty.

There will be no charge for parts, labor, or forward and return shipment during the first three months of this warranty.

There will be no charge for parts, labor, or return shipment during the fourth through twelfth month of this warranty.

Except for such repair or replacement, we will not be liable for any incidental damages or for any consequential damages, as those terms are defined in Section 2-715 of the Uniform Commercial Code, in connection with products covered by this warranty.

BOONTON

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BOONTON

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